Differential station coordinate changes (velocities) versus coordinate differences for interpolating or extrapolating surface point motions

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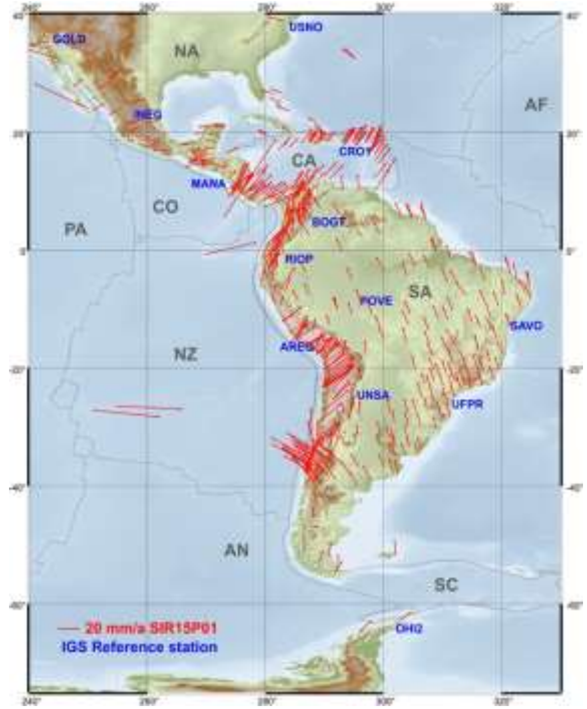
IAG 150 years

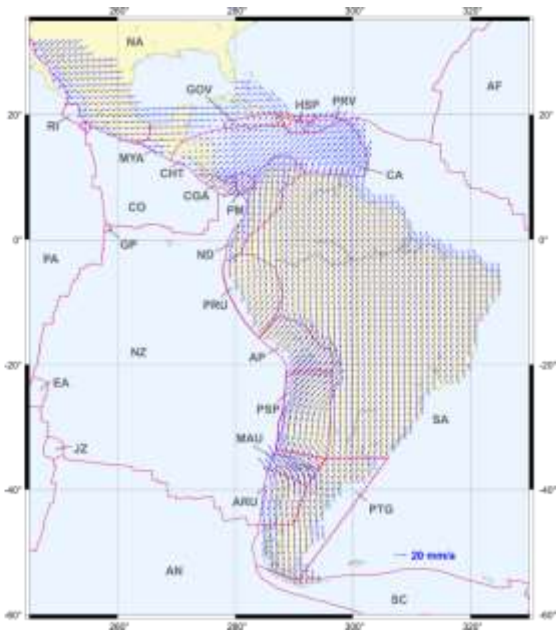
Technische Universität München

Motivation

The International Terrestrial Reference Frame (ITRF) and its regional densifications like SIRGAS provide linear coordinate derivatives d**X**/dt (constant velocities **v**) for interpolating or extrapolating the station coordinates to an arbitrary epoch, e.g. for satellite tracking or as reference stations for terrestrial positioning.



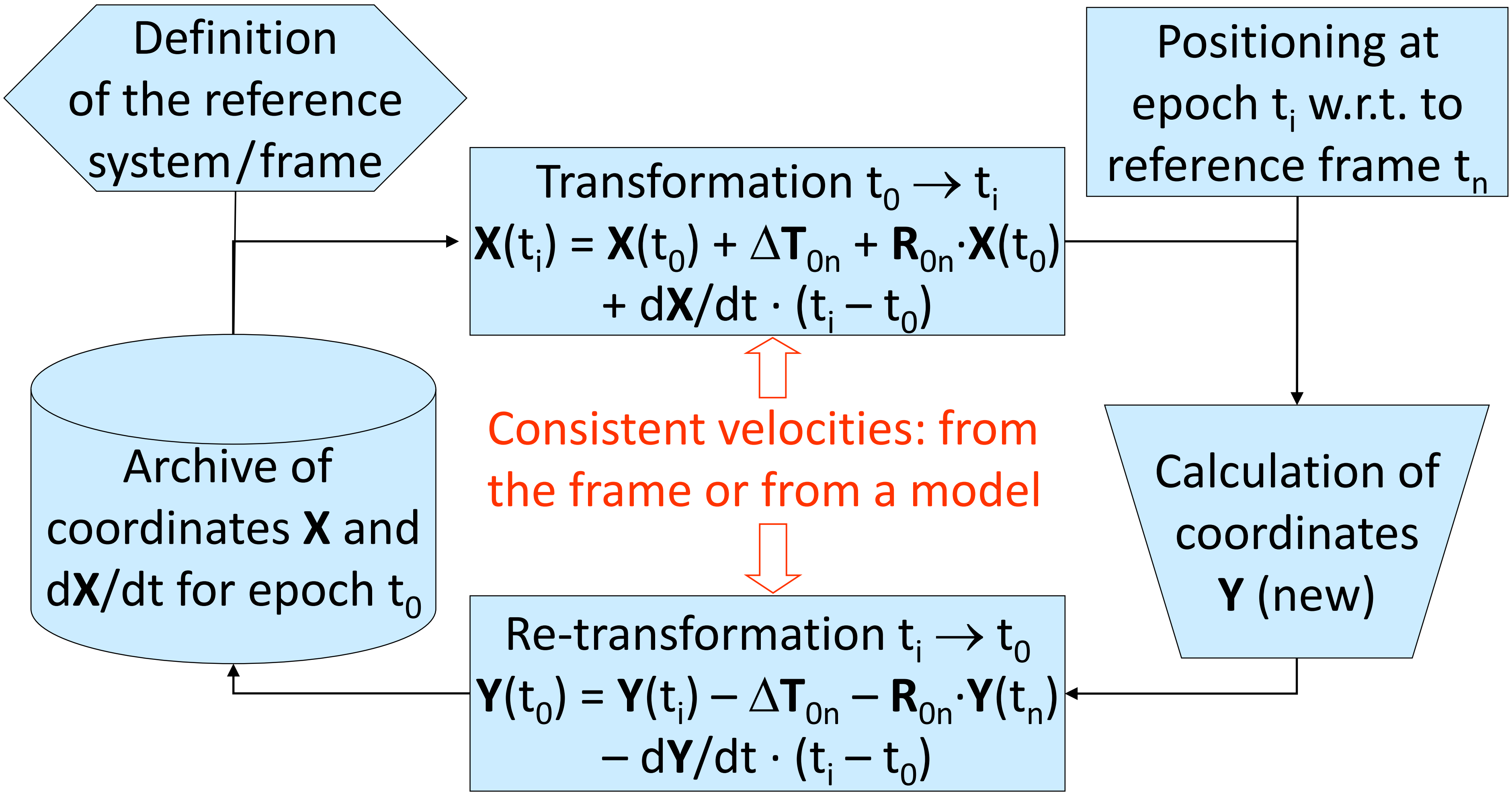
SIR15P01 velocities



VEMOS 2015

These velocities are also used for geographical interpolation of the movements of other stations, e.g. used in engineering, surveying, precise navigation or global change studies.

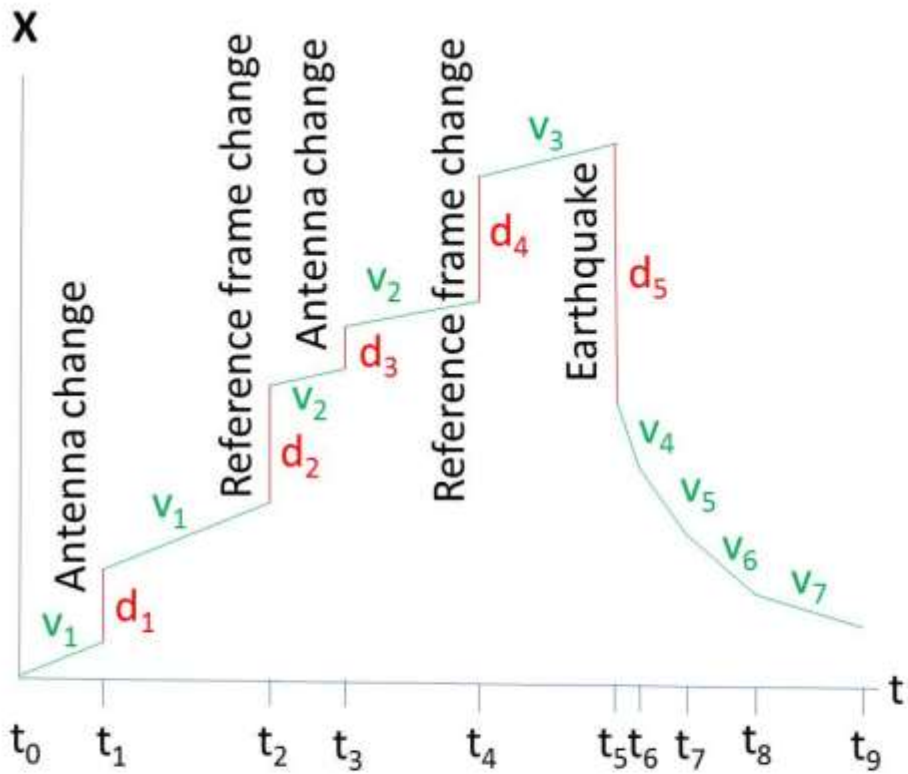
Use of the terrestrial reference frame



(Literature: e.g. Drewes 2004 … 2015)

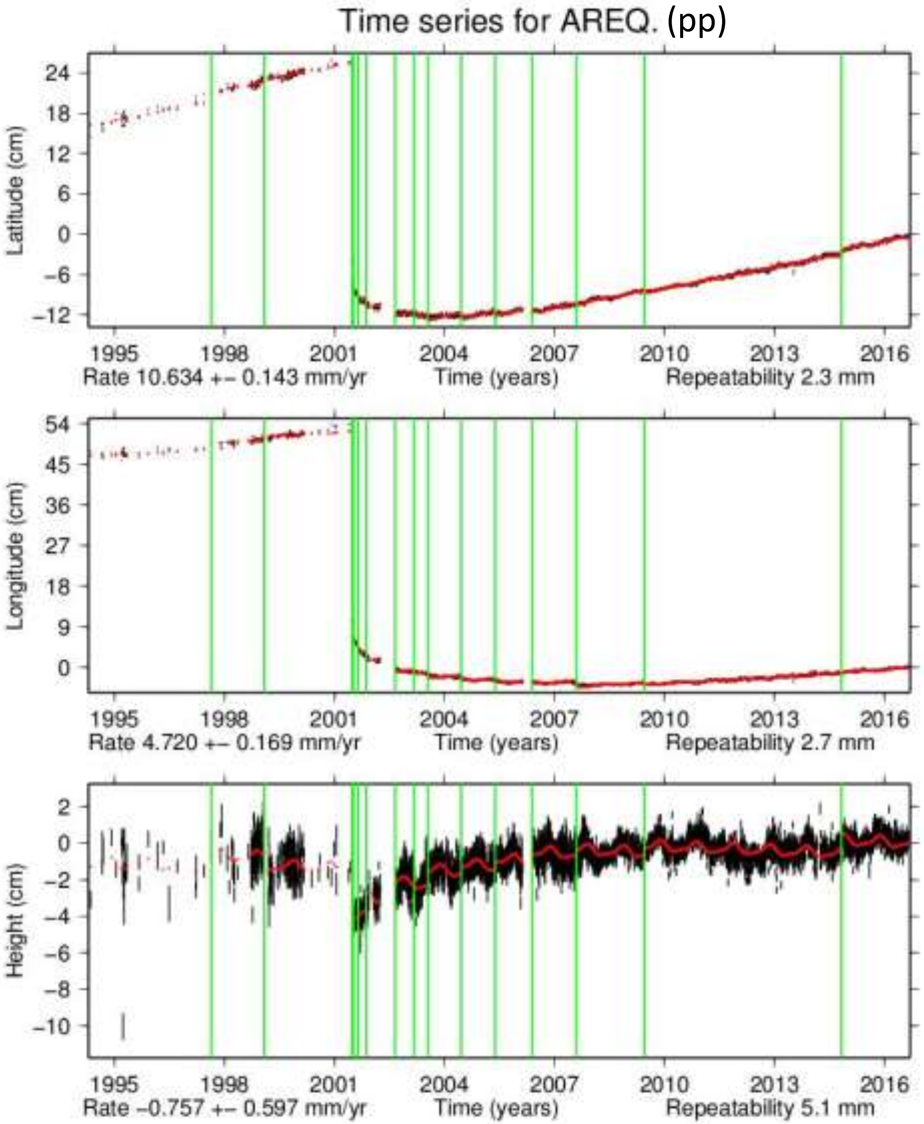
Examples for inconstant velocities: 1. Earthquakes

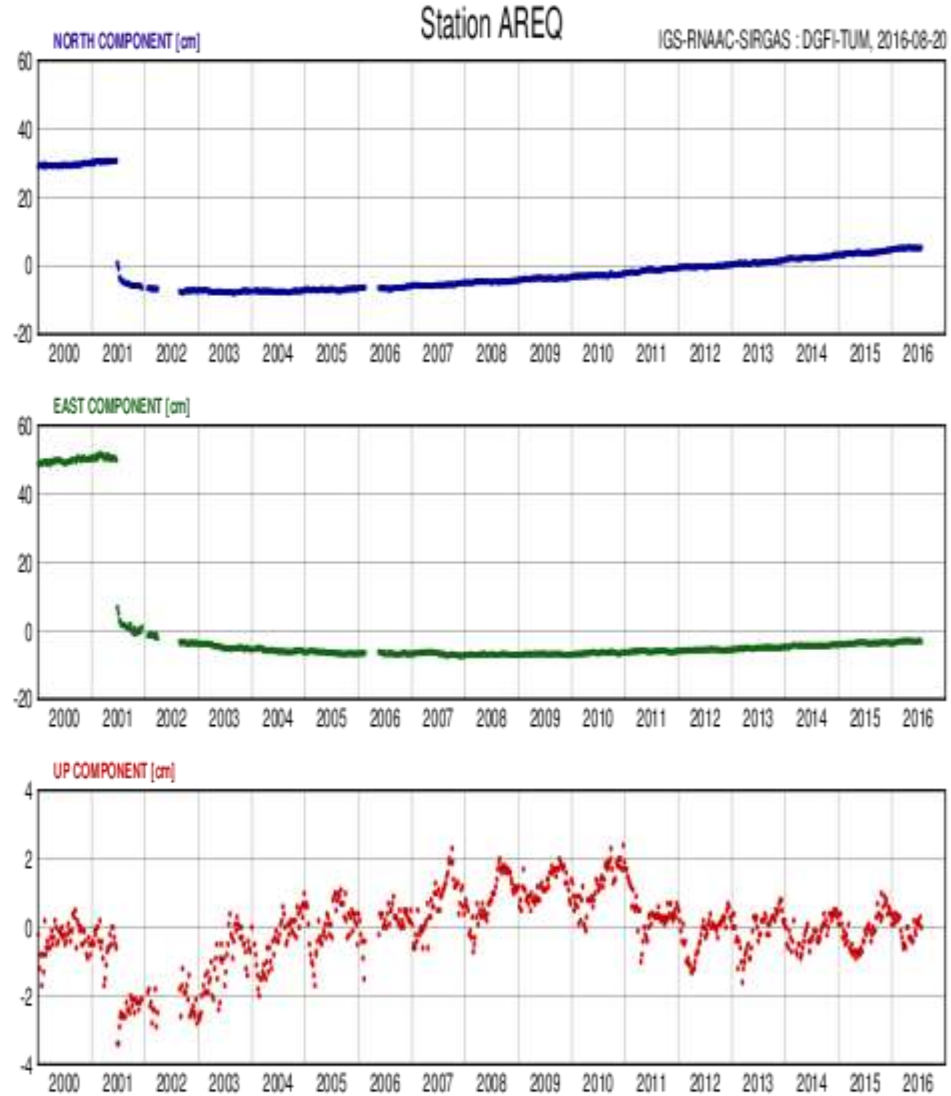
If the velocities are not constant, e.g. due to effects caused by *seismic events*, other *non-linear surface deformations,* or artificially by *changes of antennae* or the *reference frame*, the interpolation or extrapolation between epochs t_0 and t_i has to be done stepwise over all contemplable periods and effects.



If a new station is positioned at t_i and shall be re-transformed to the reference epoch t_0, the geographical interpolation has to follow backwards the same procedure over all the periods, which may be very inefficient, in particular in unstable (seismic) regions.

Examples for inconstant velocities: 1. Earthquakes

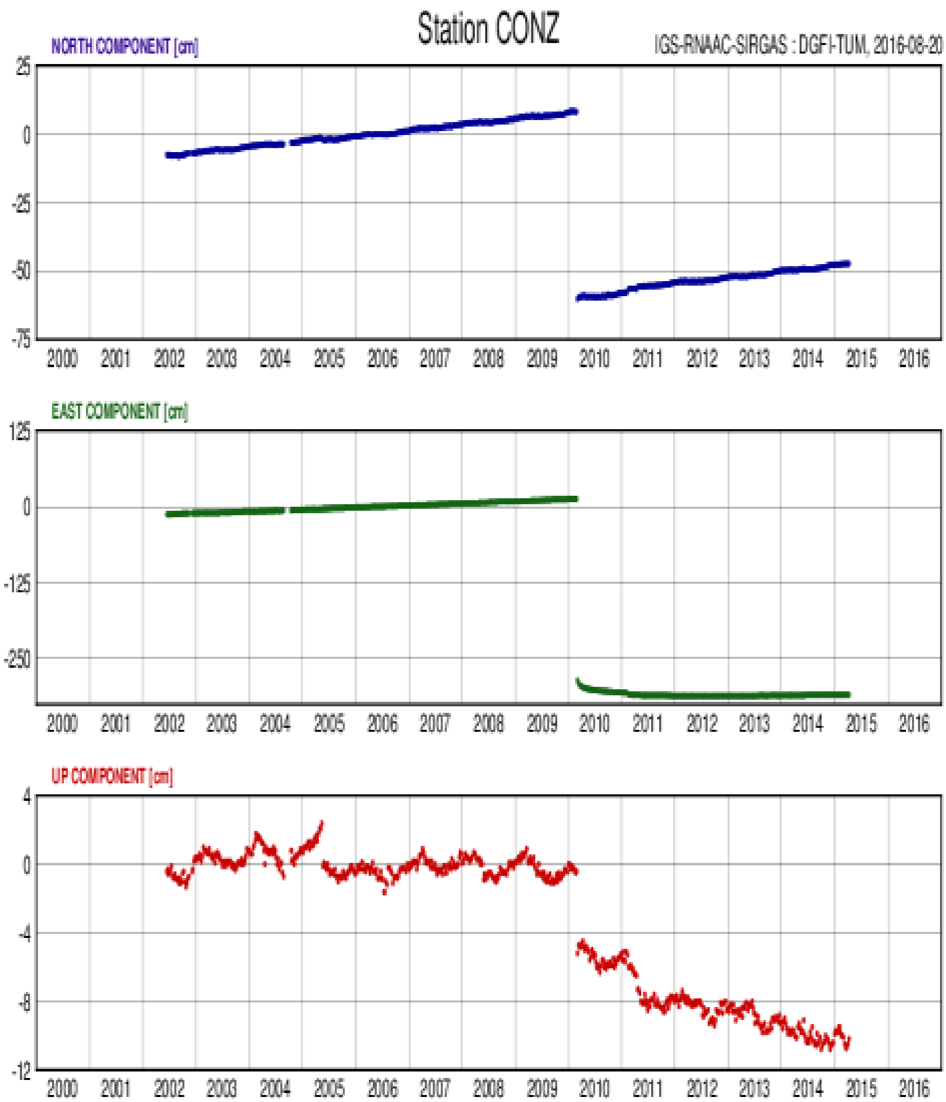




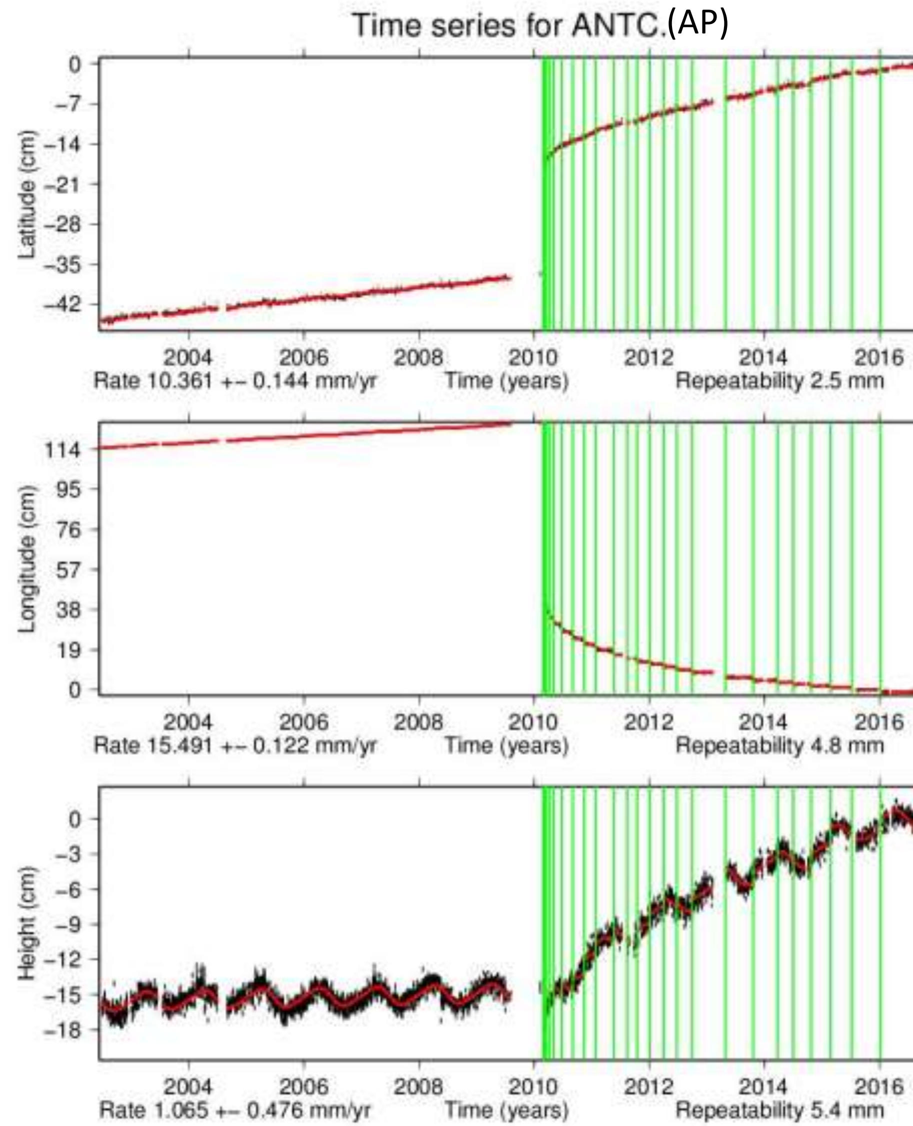
from sideshow.jpl.nasa.gov_post_series

from sirgas.org

1. Earthquakes (continued)



from sirgas.org



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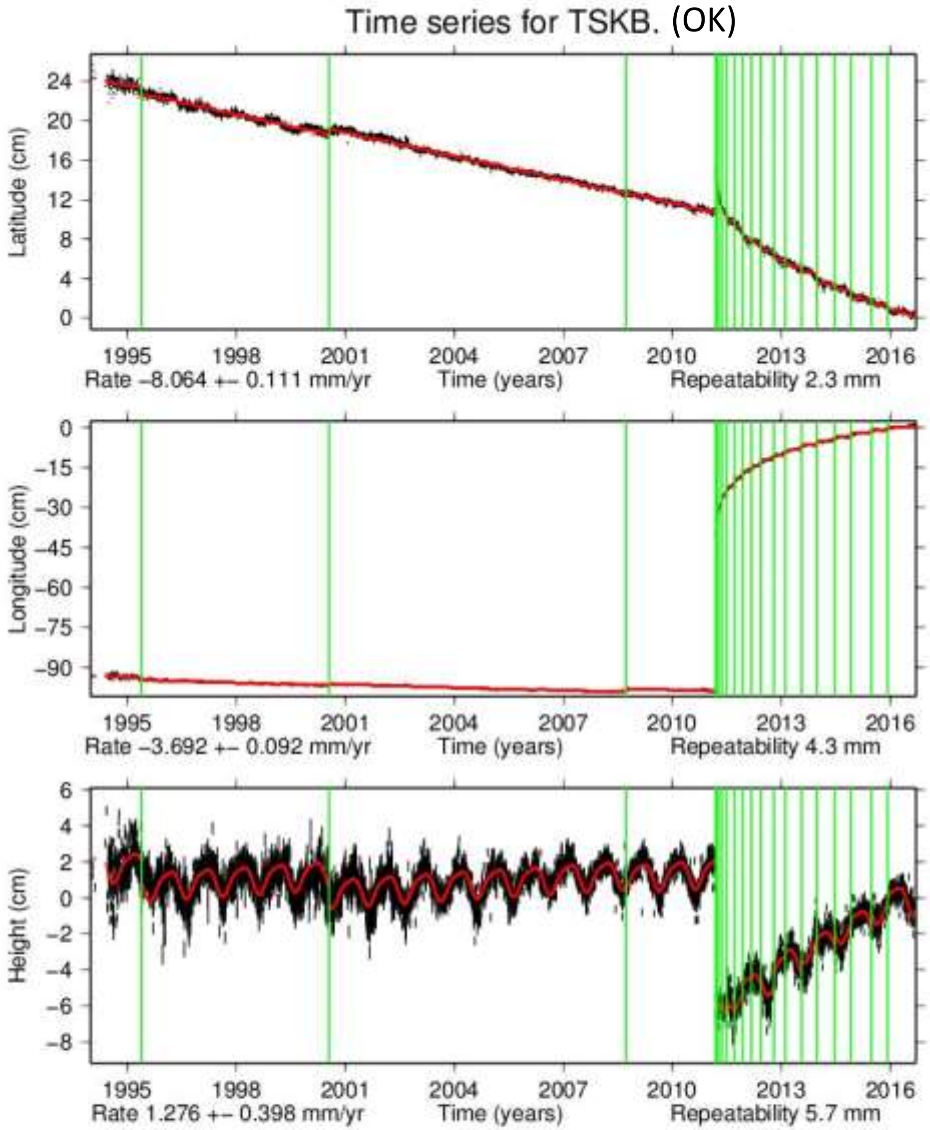
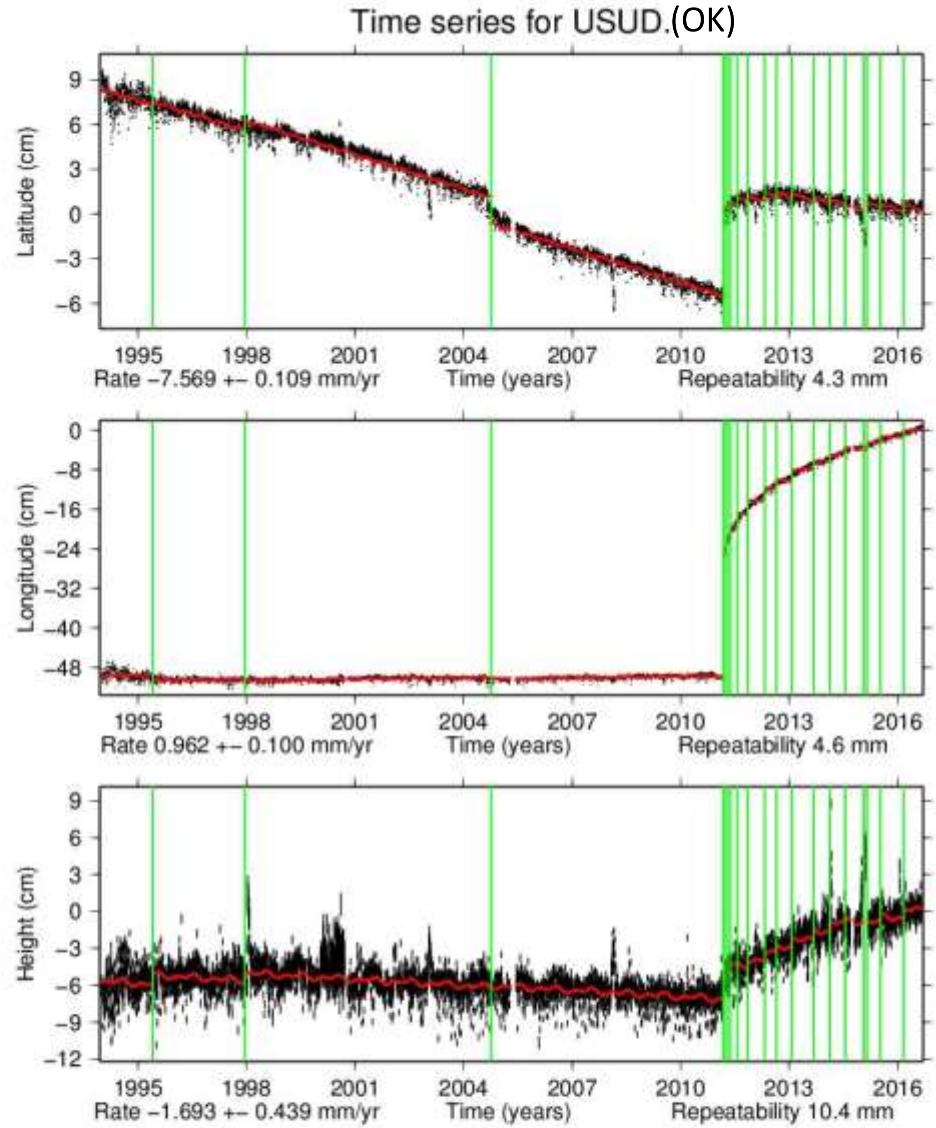
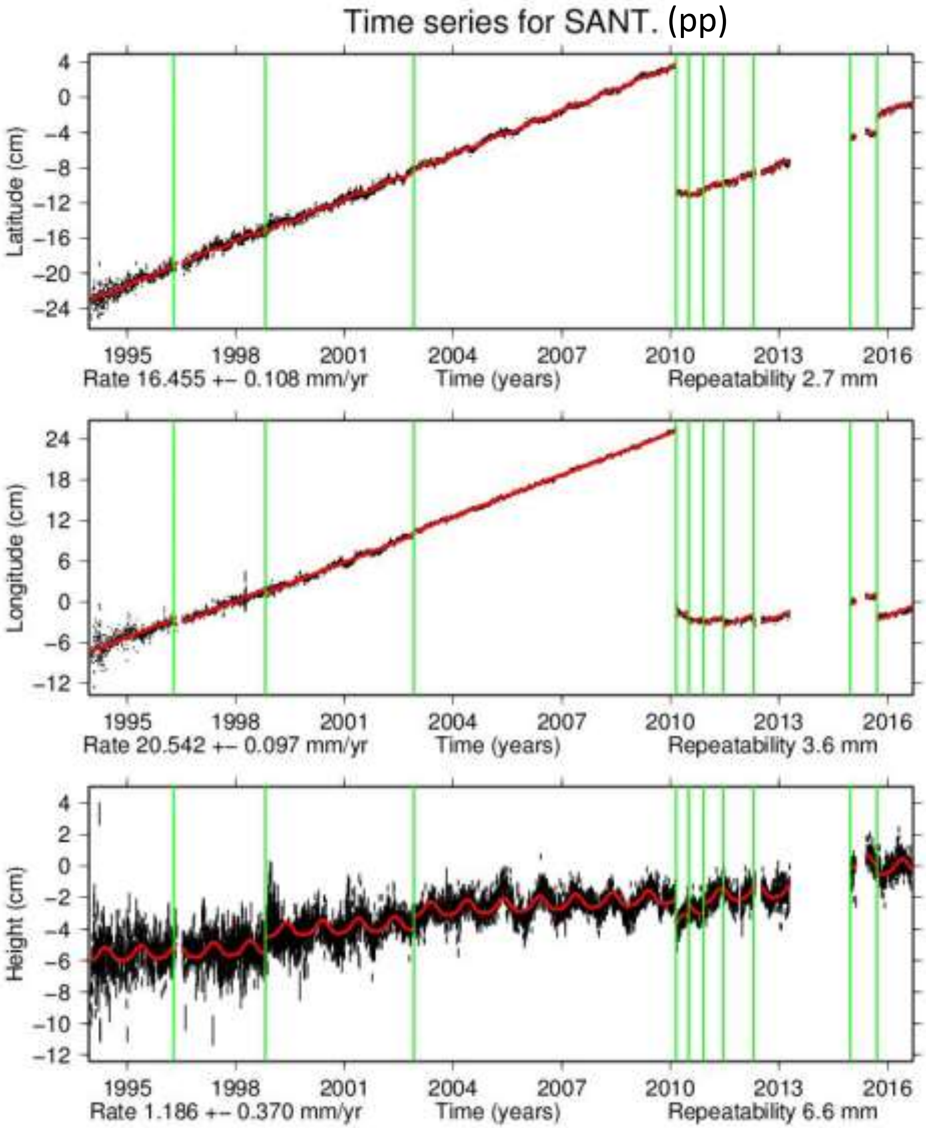
1. Earthquakes (continued)

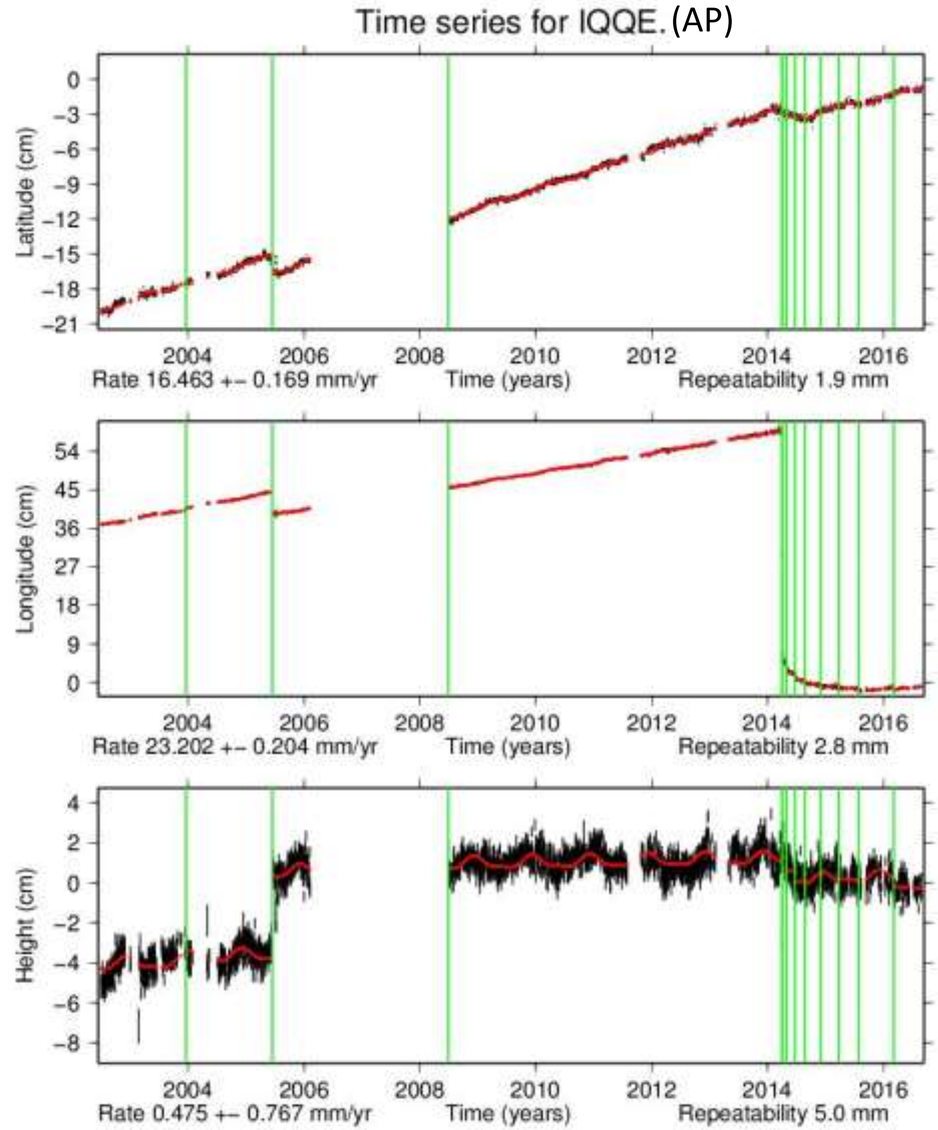




from sideshow.jpl.nasa.gov_post_series

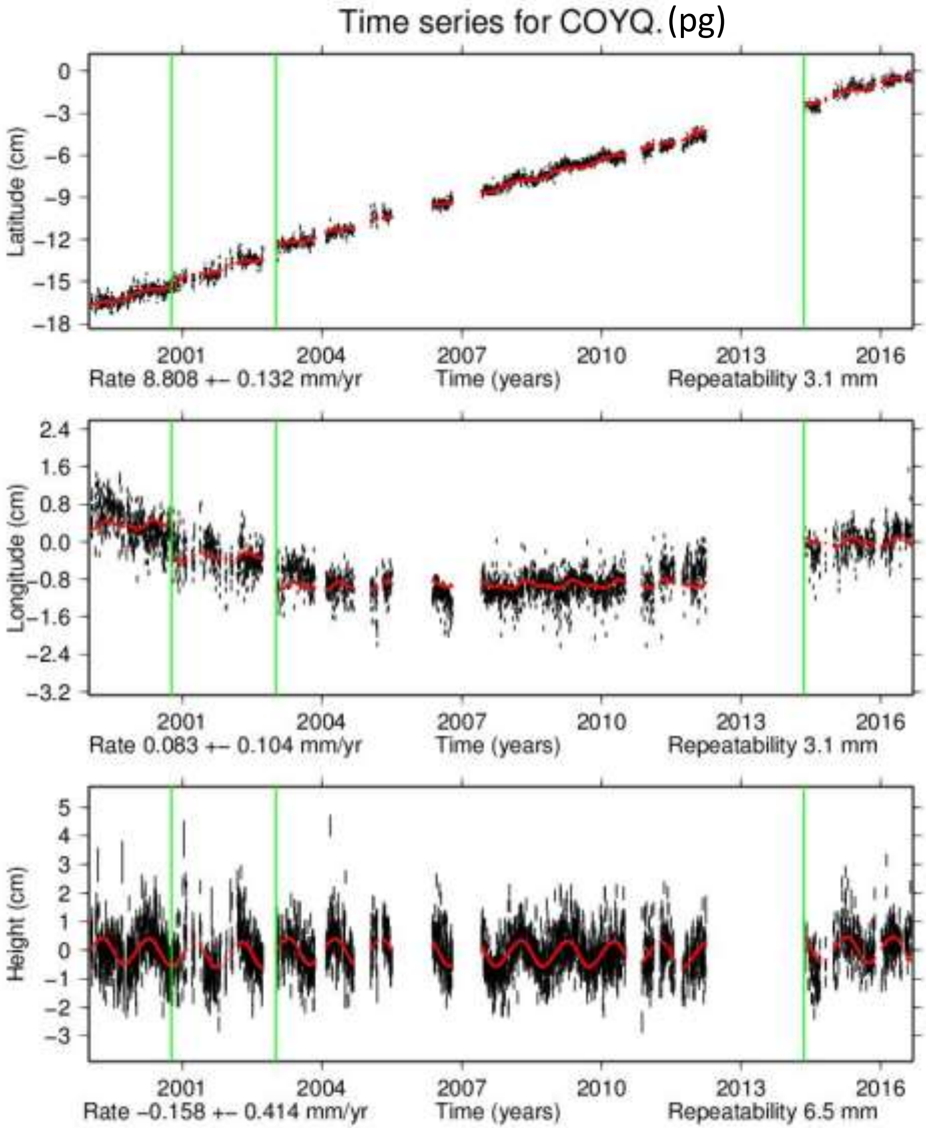
2. Earthquakes and antenna changes

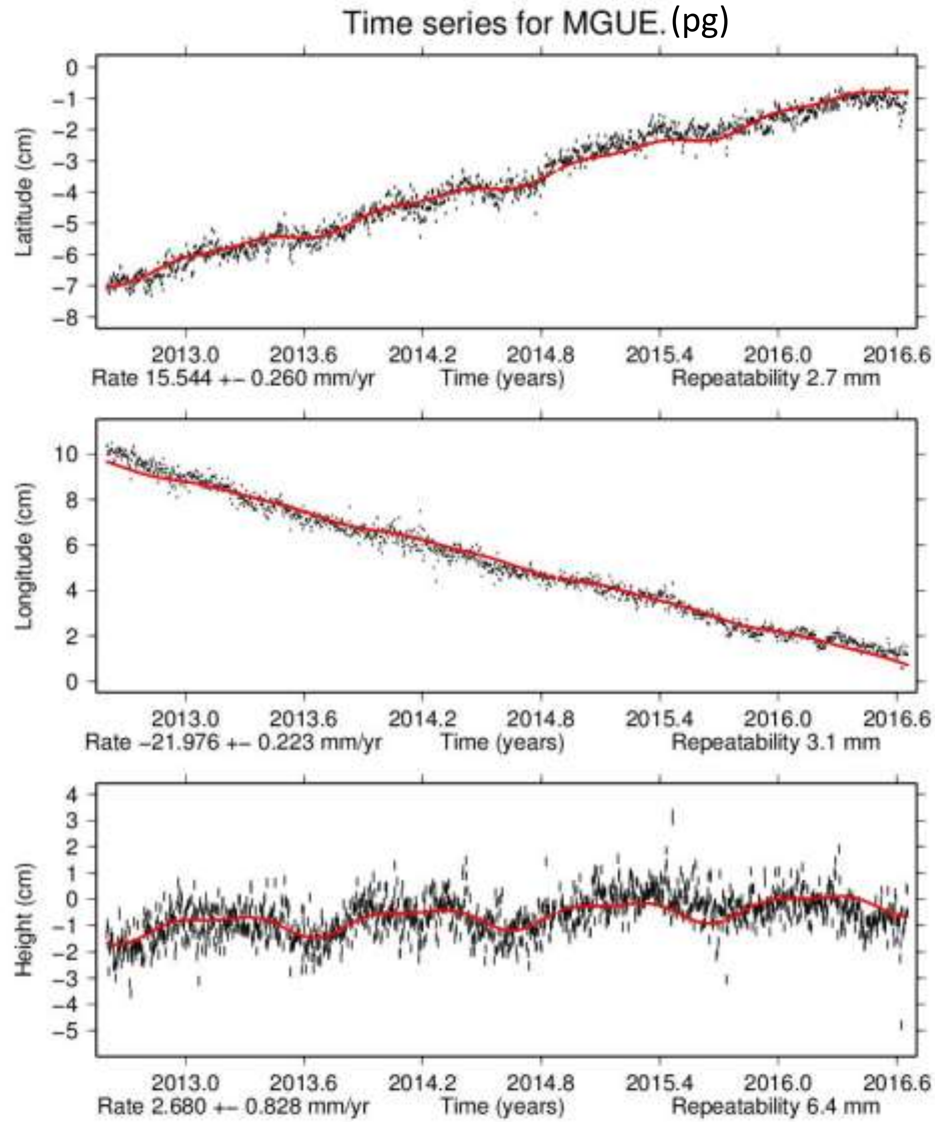




from sideshow.jpl.nasa.gov_post_series

3. Non-linear station movements





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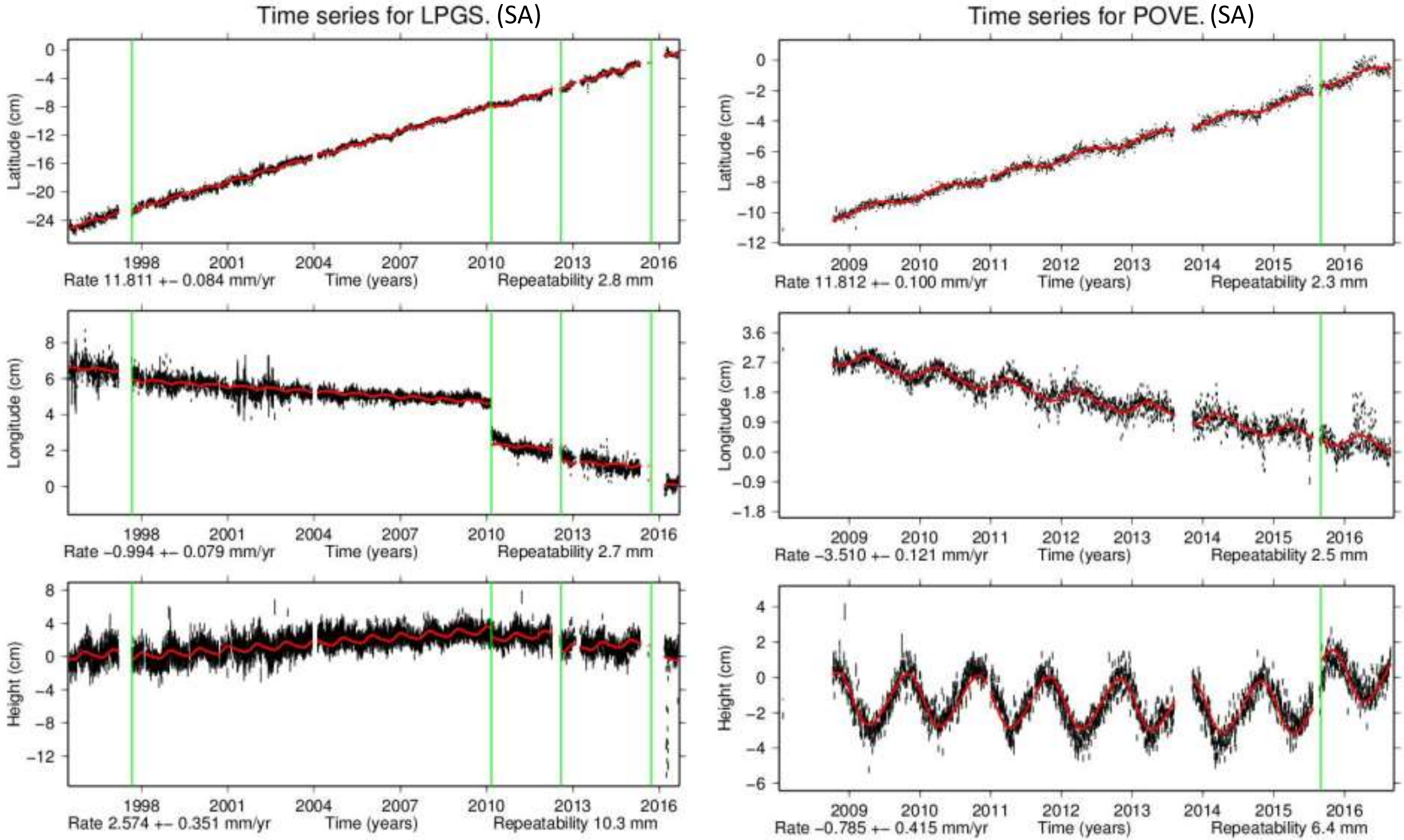

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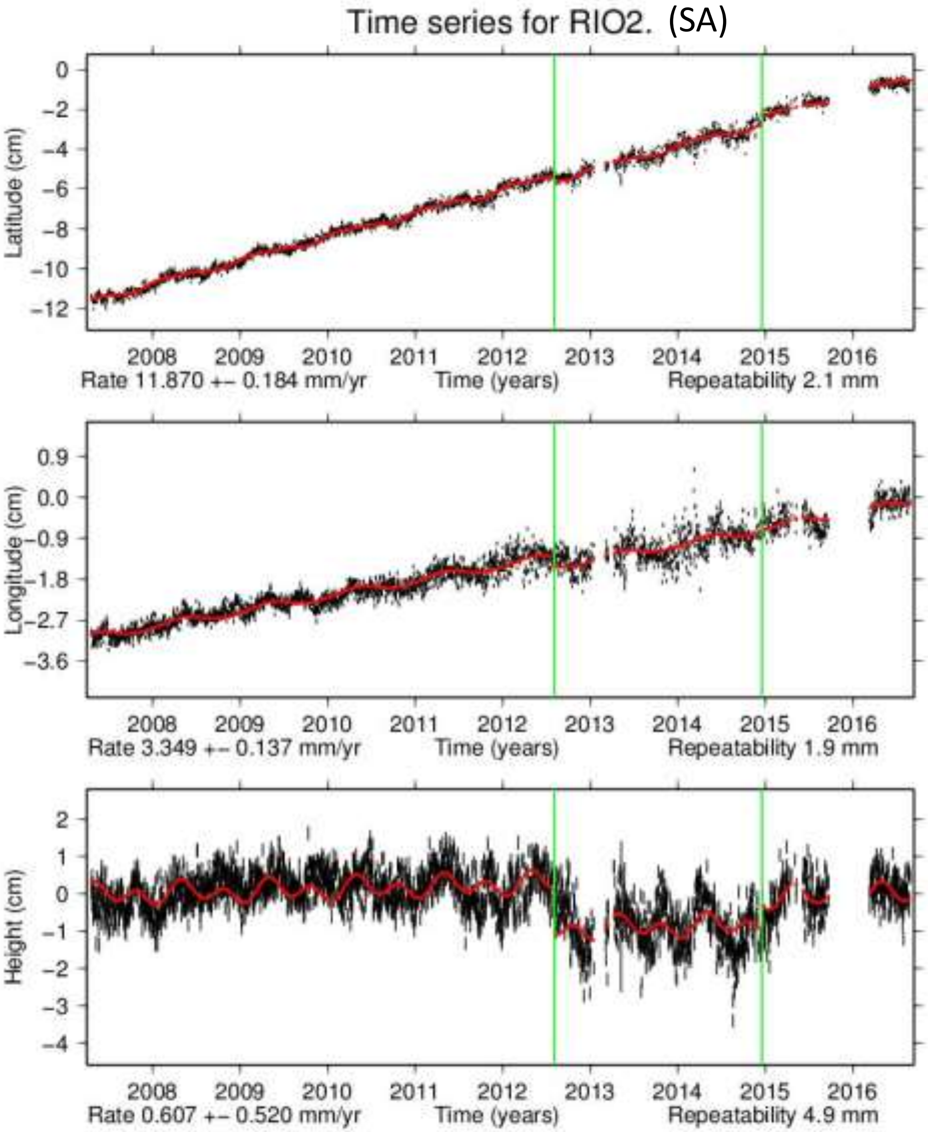

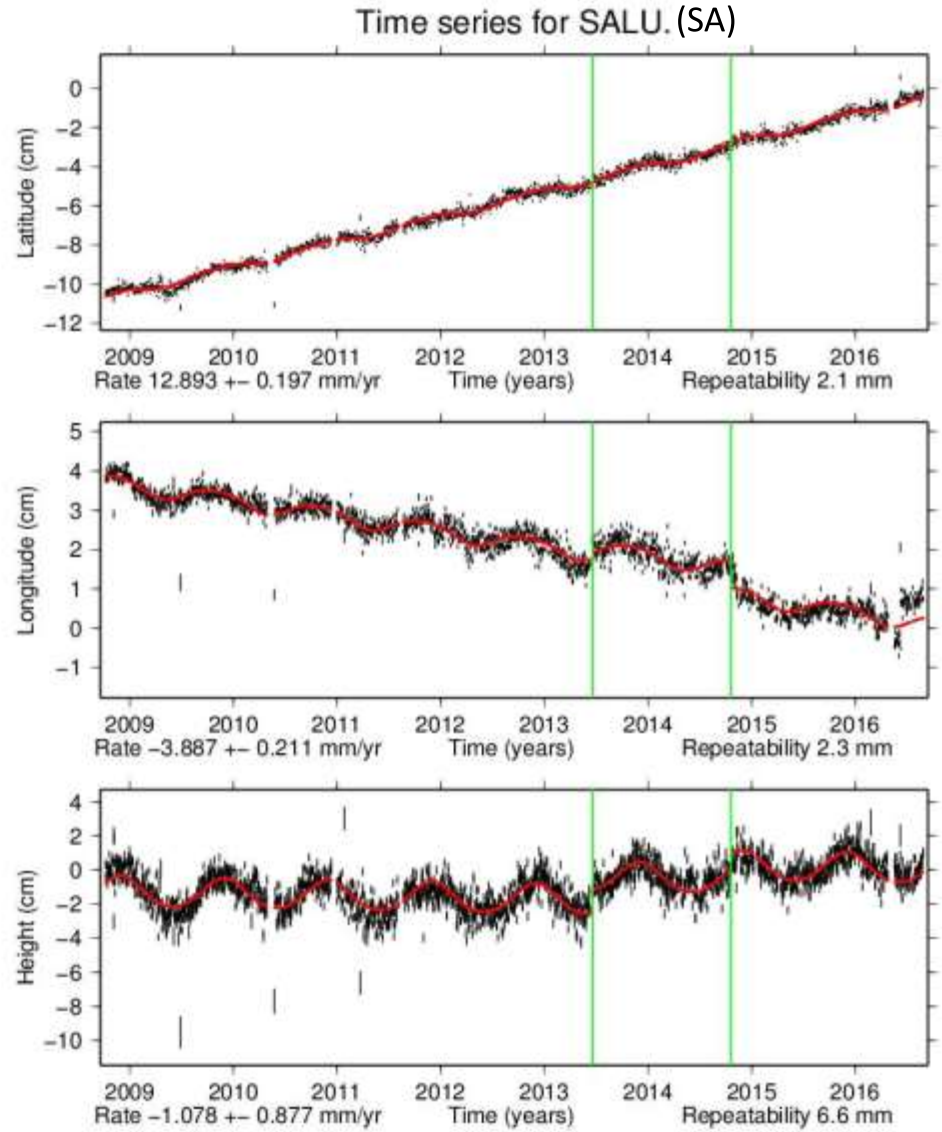

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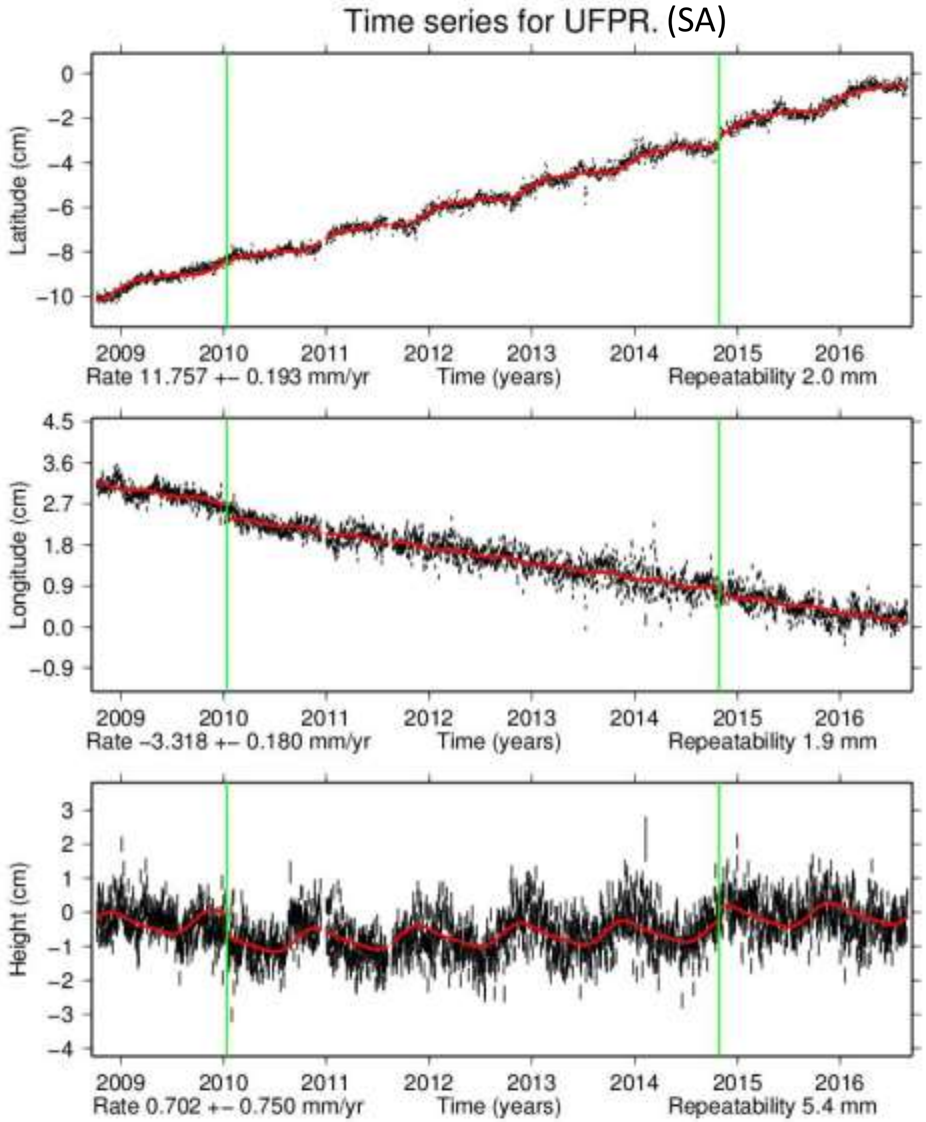

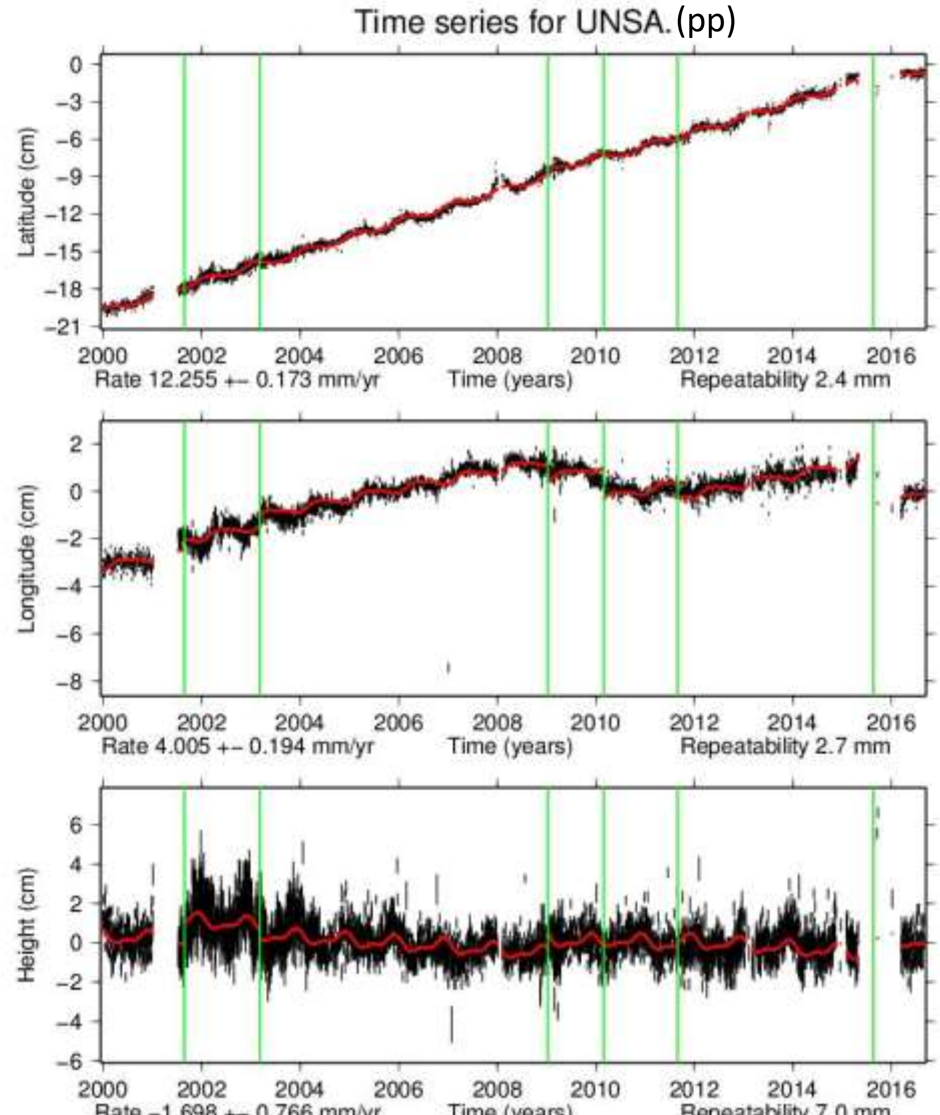

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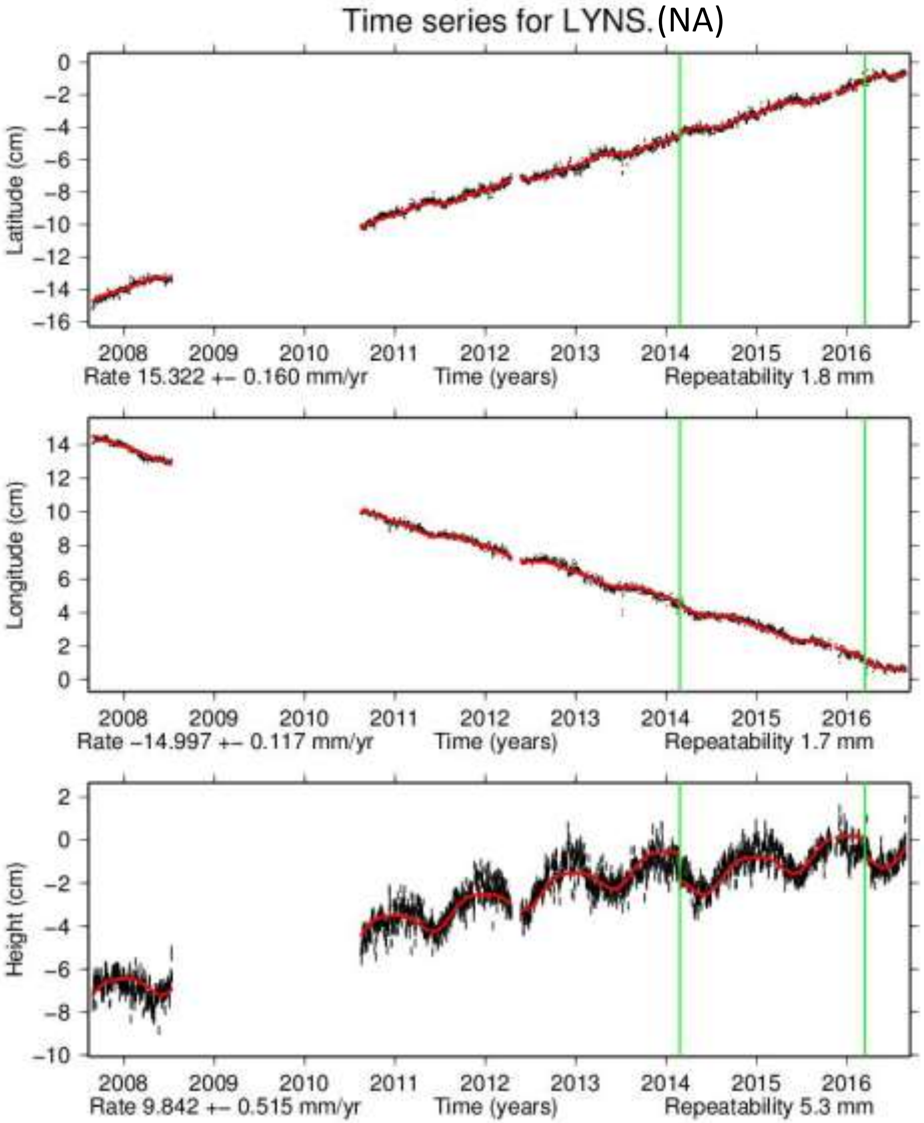

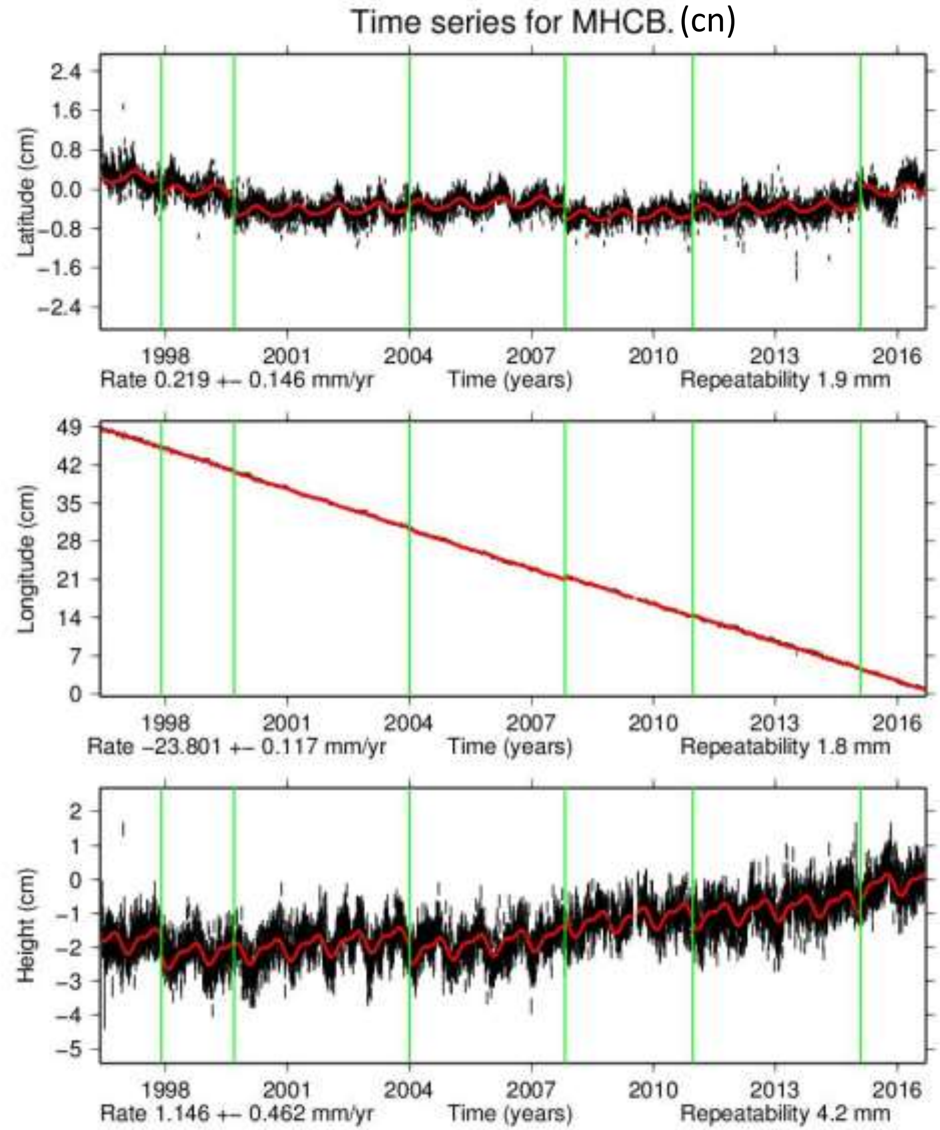

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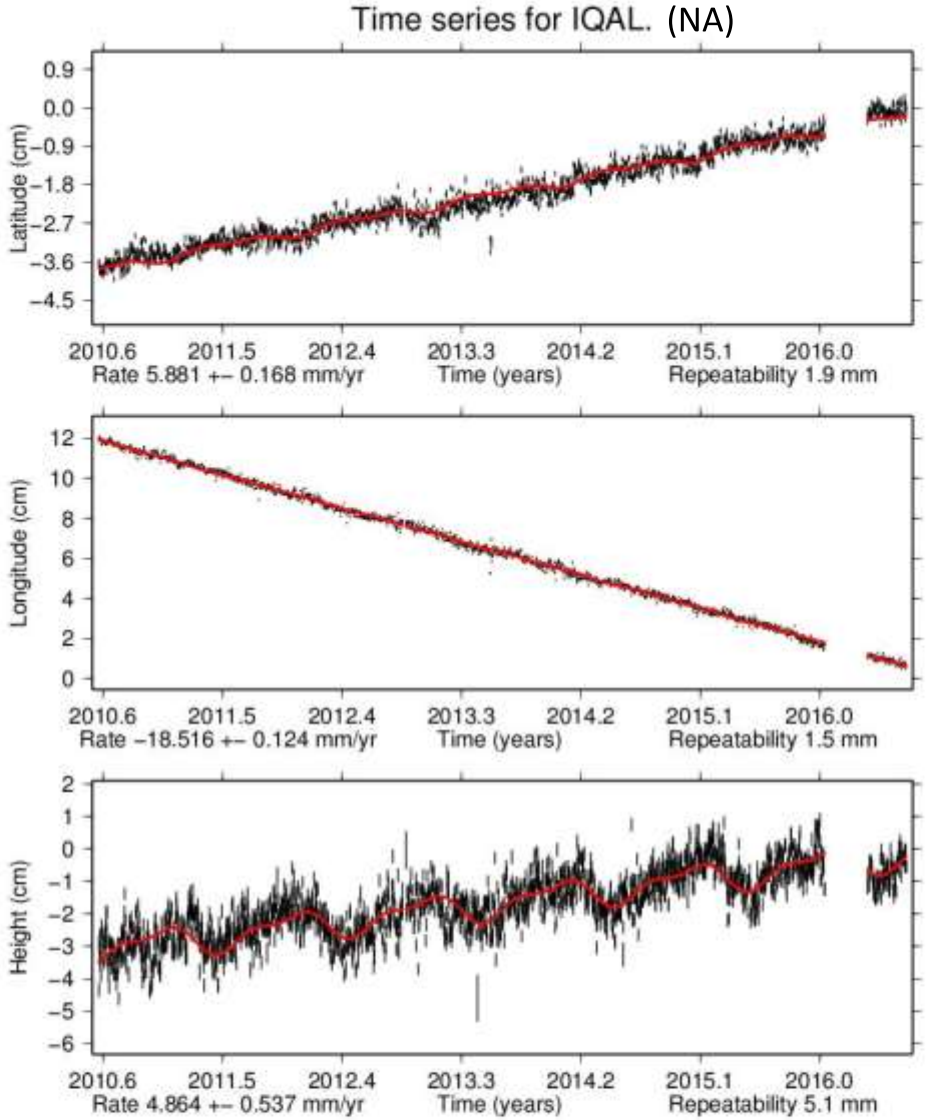

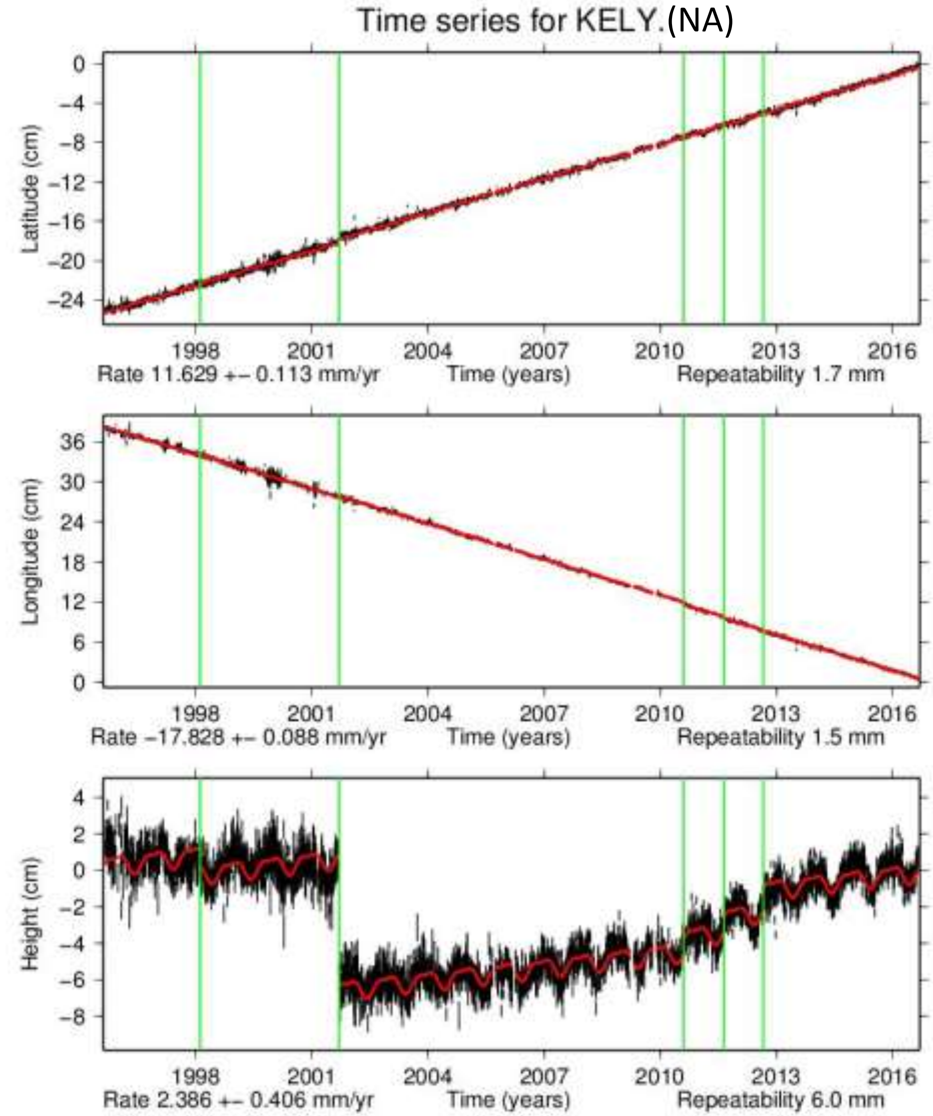

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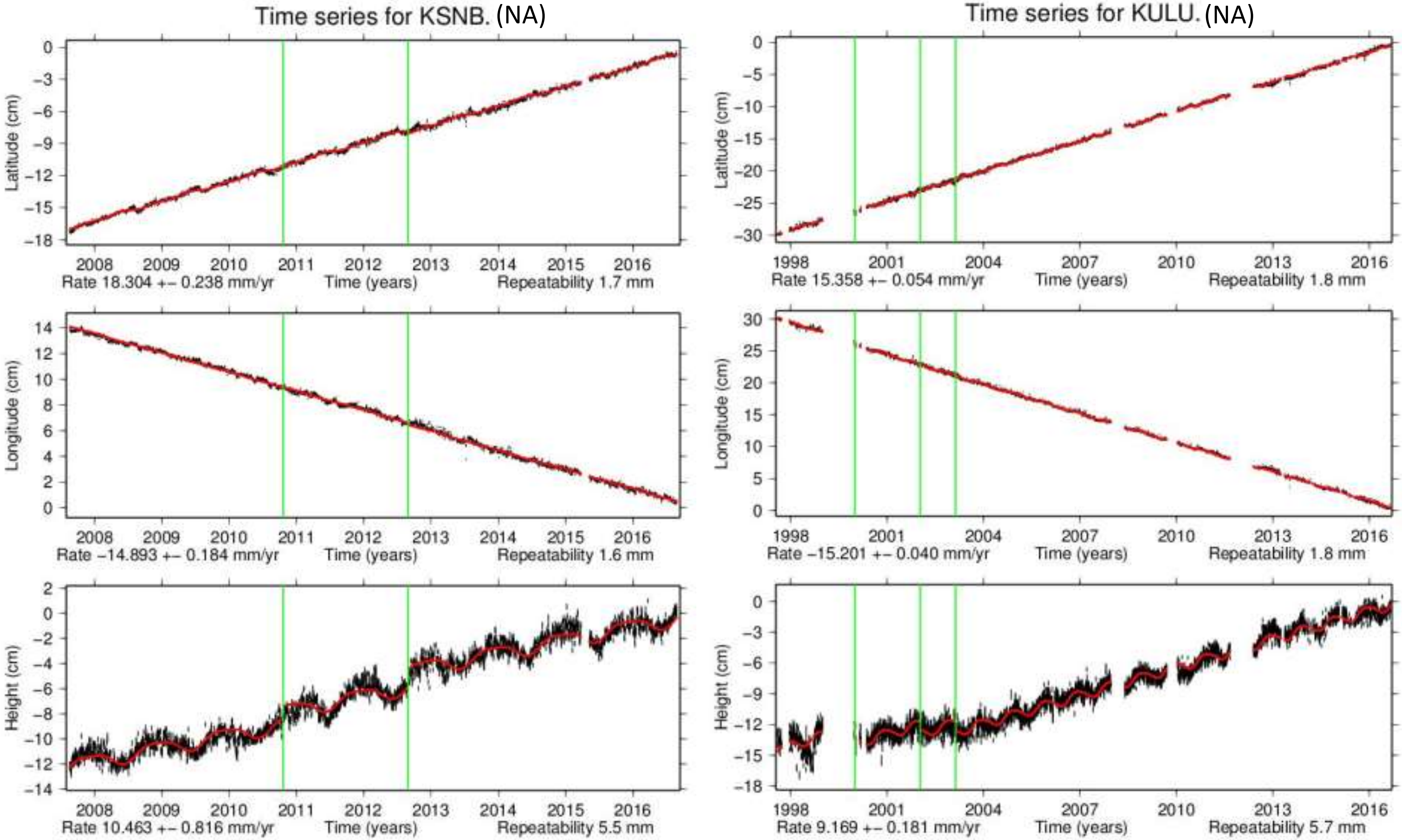

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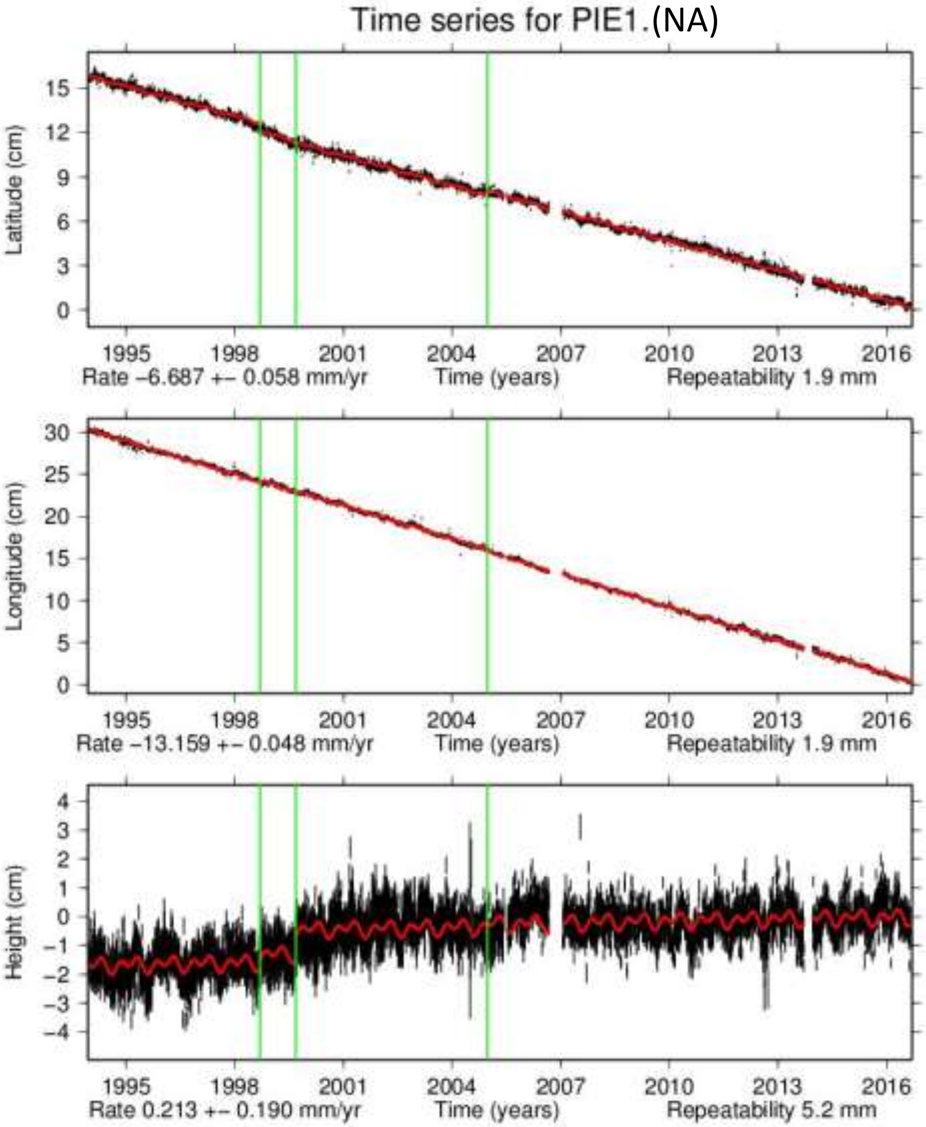

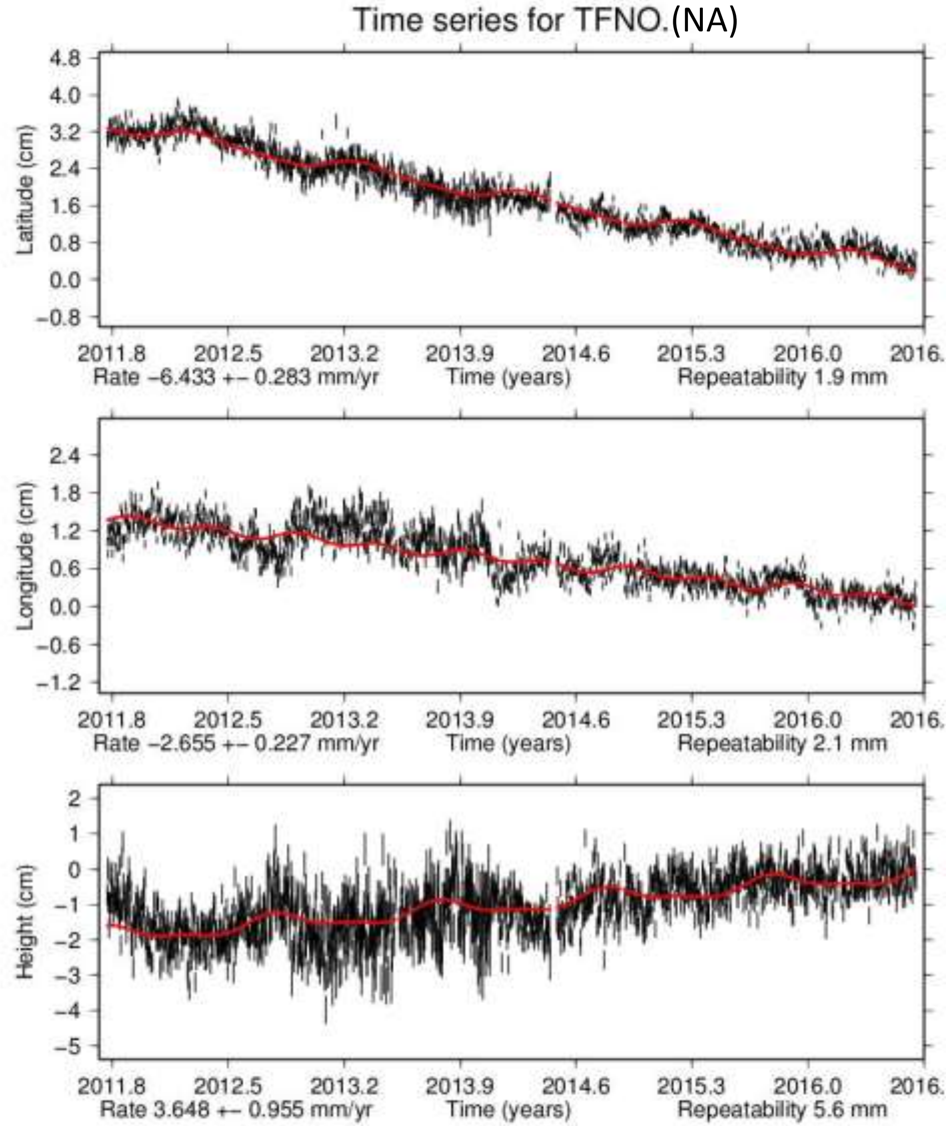

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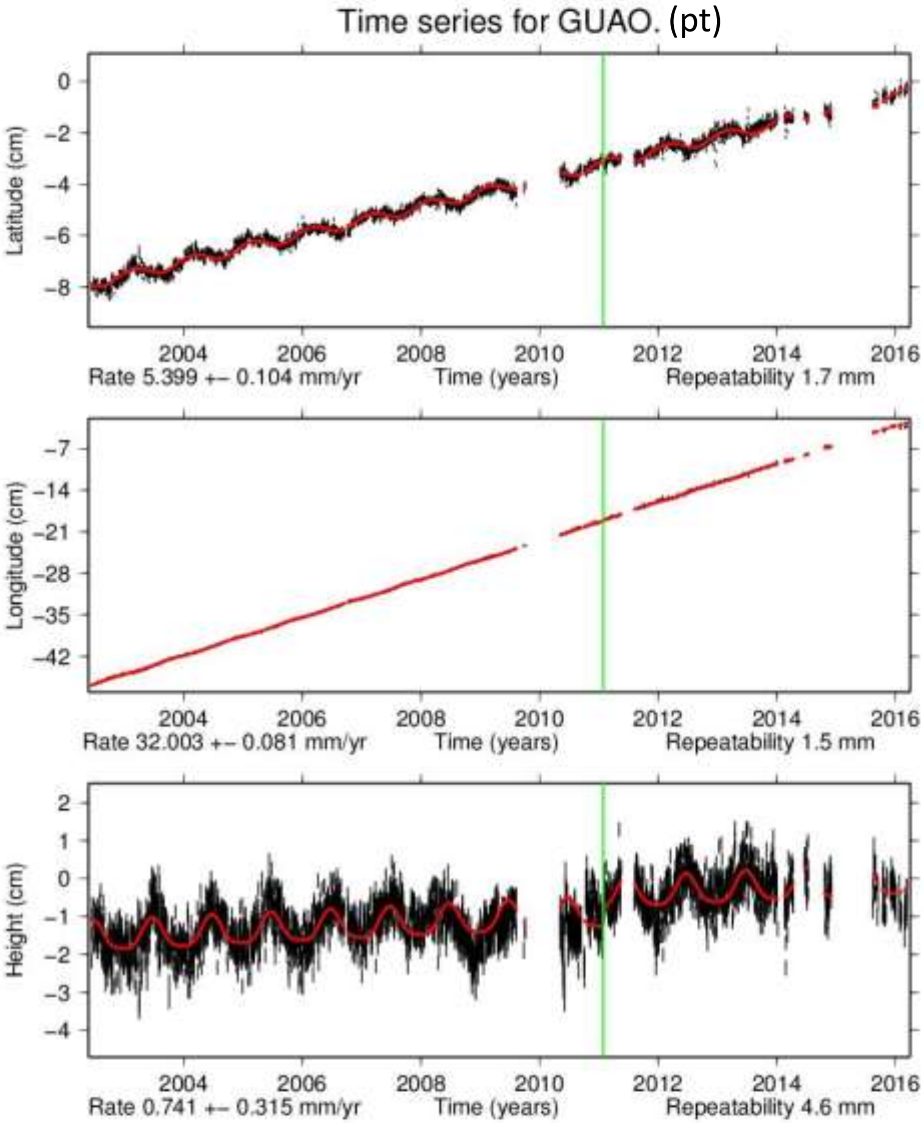

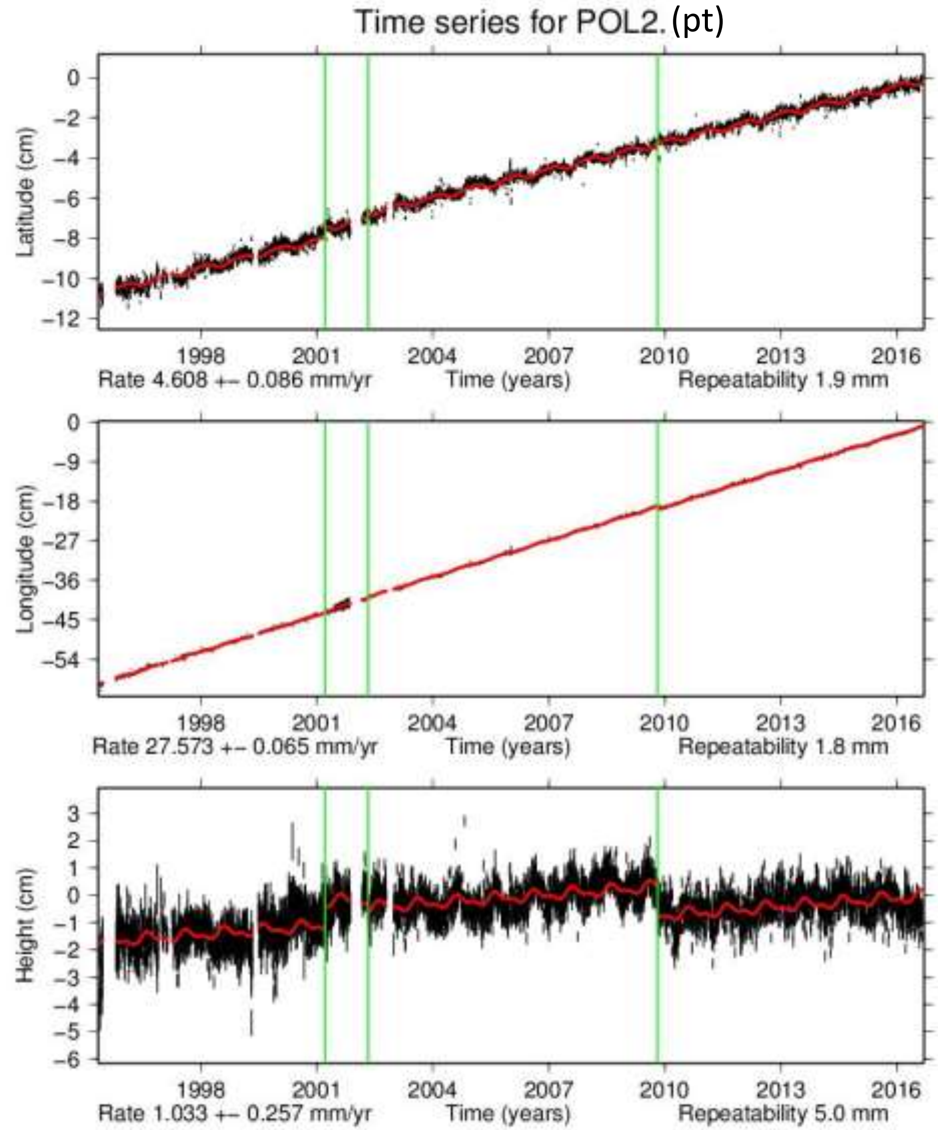

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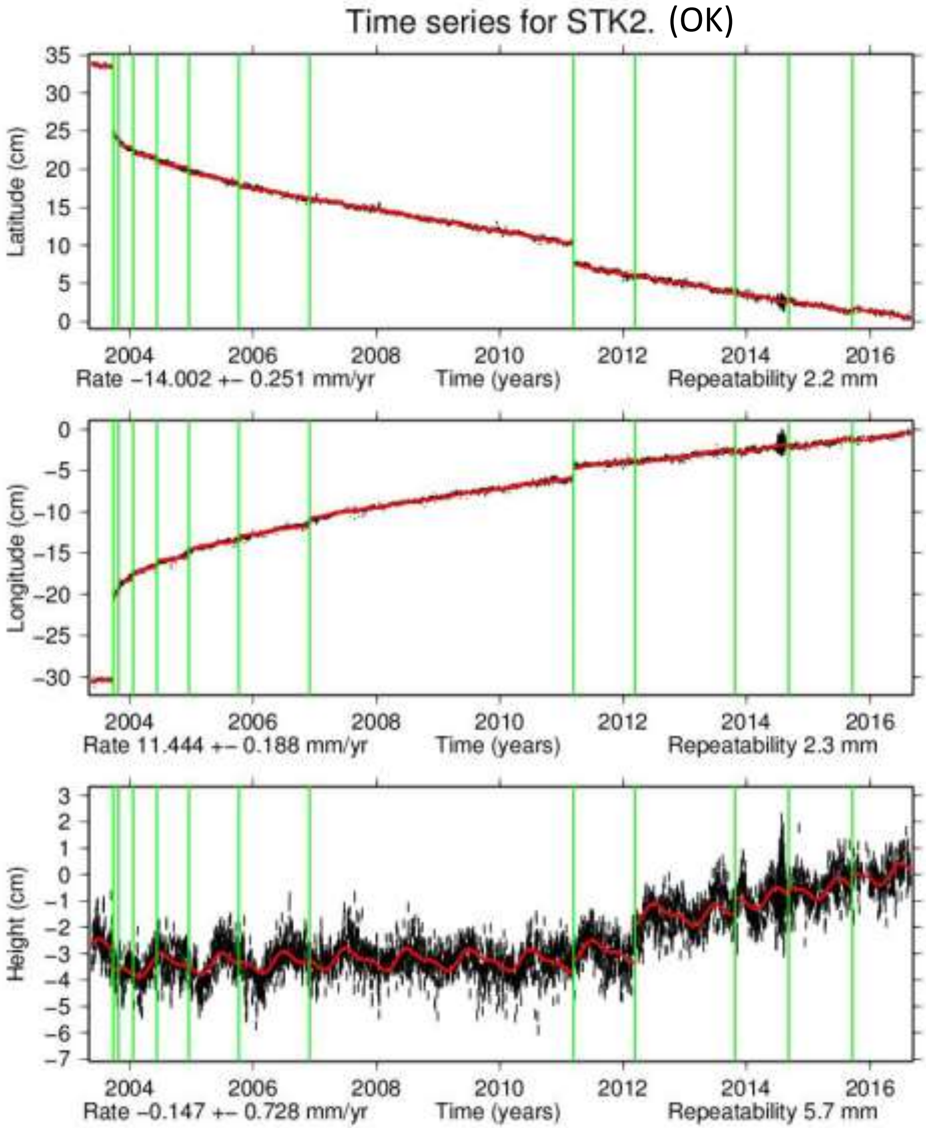

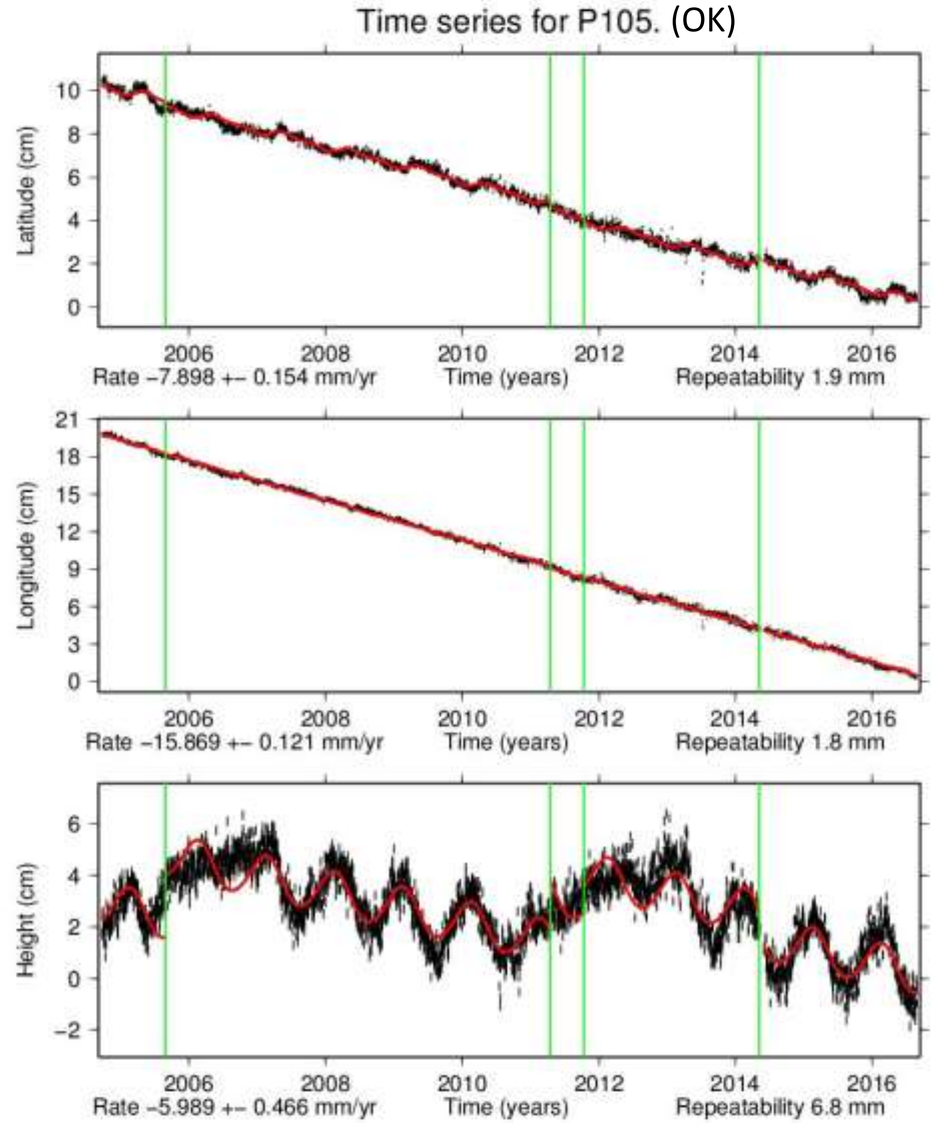

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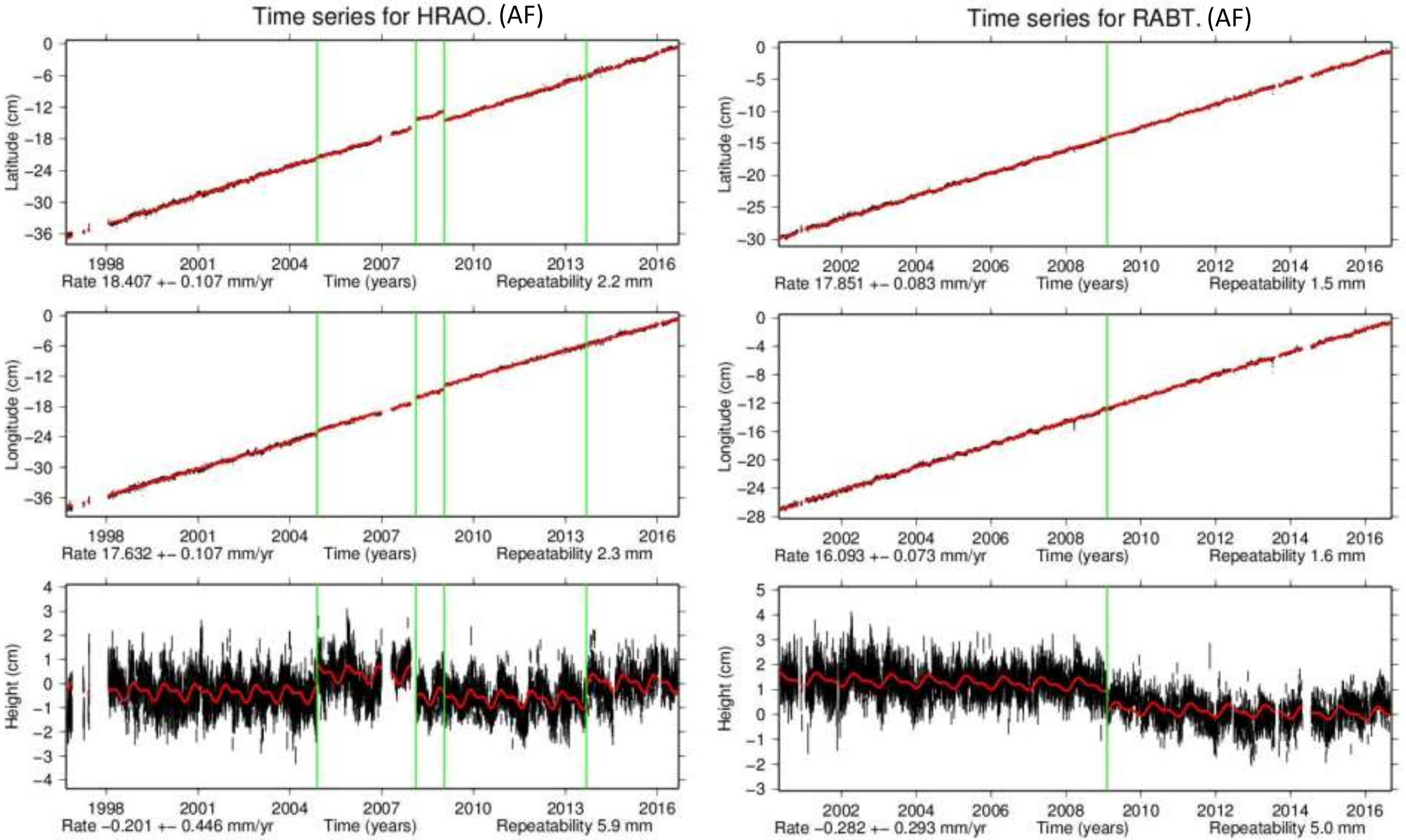

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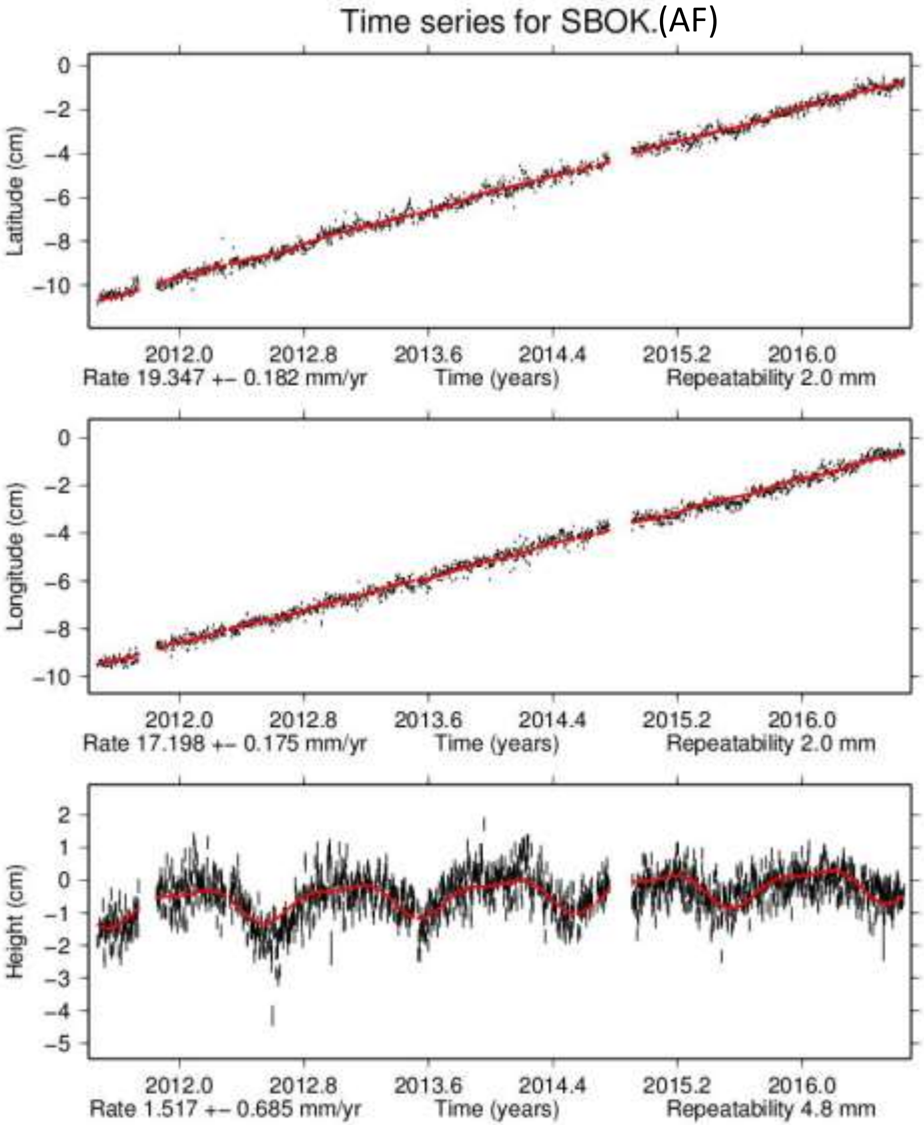

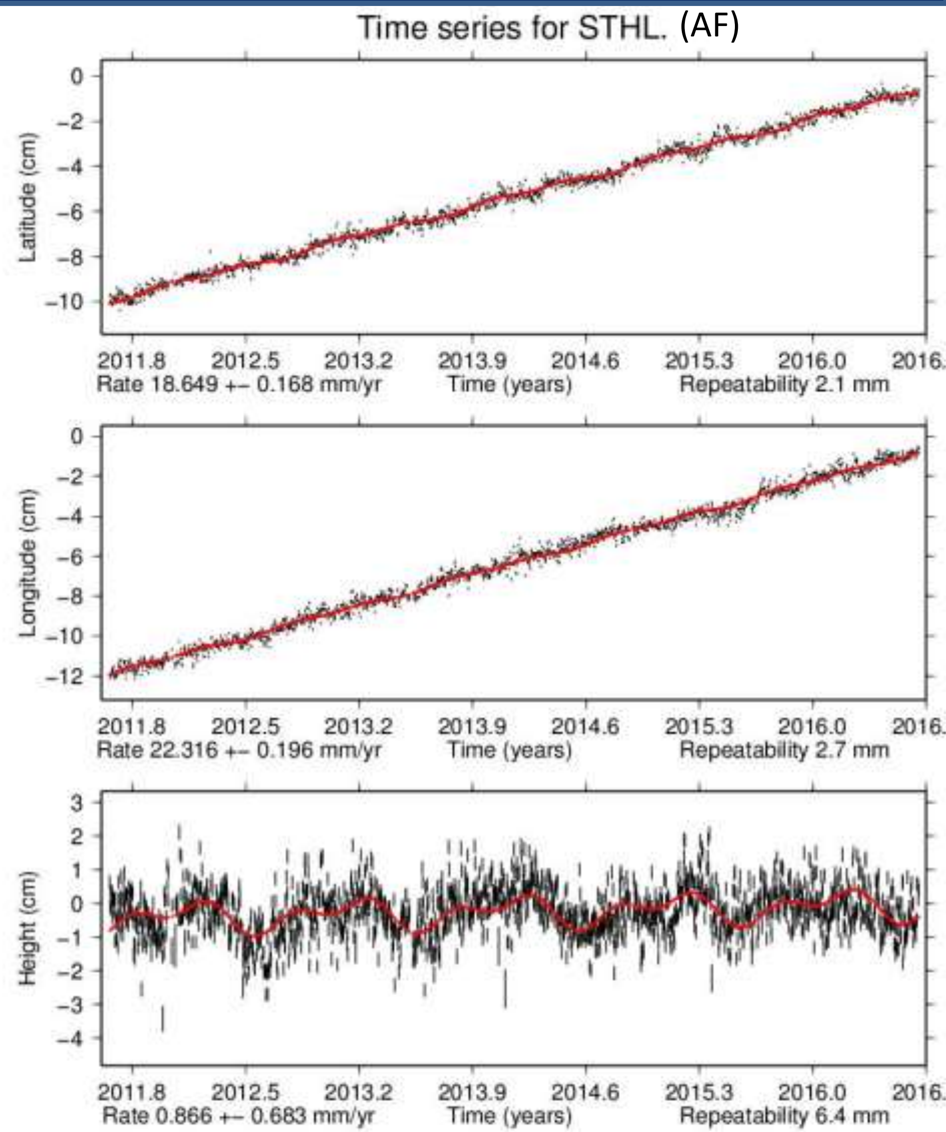

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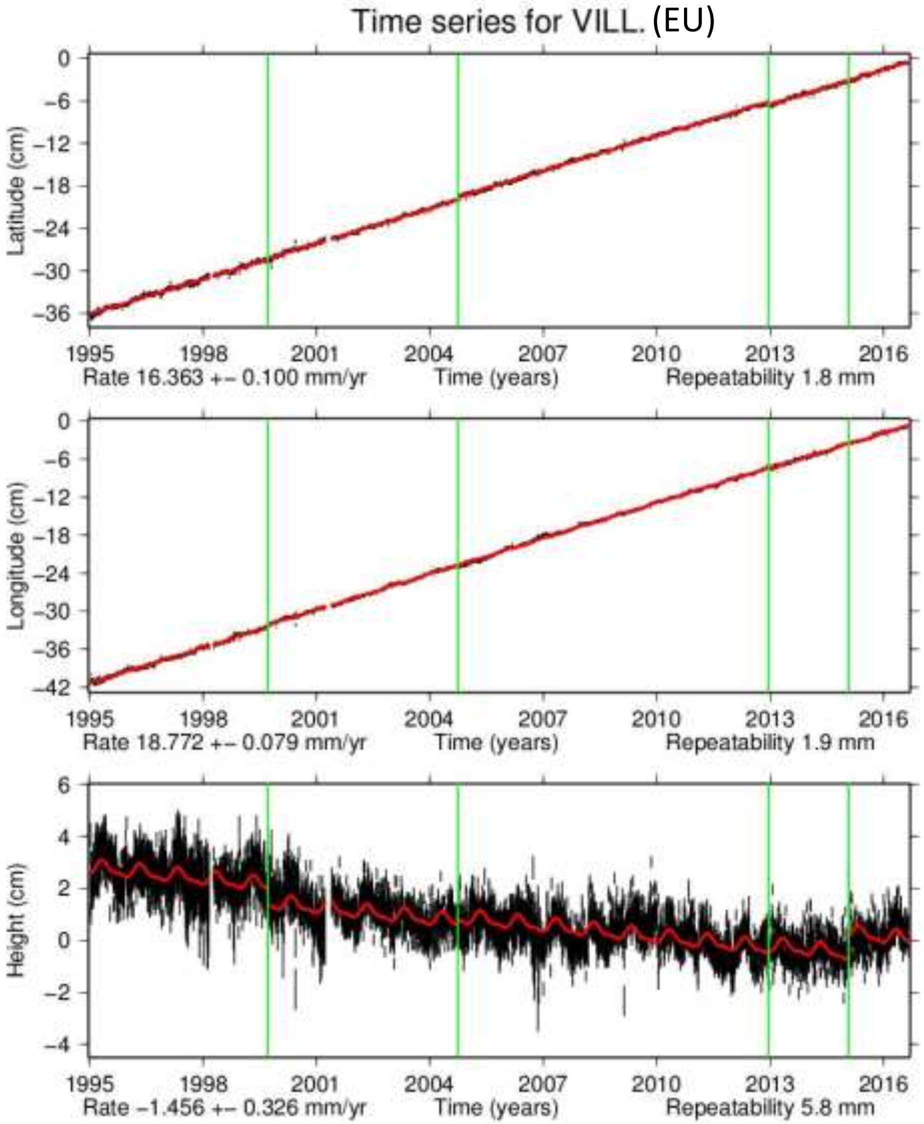

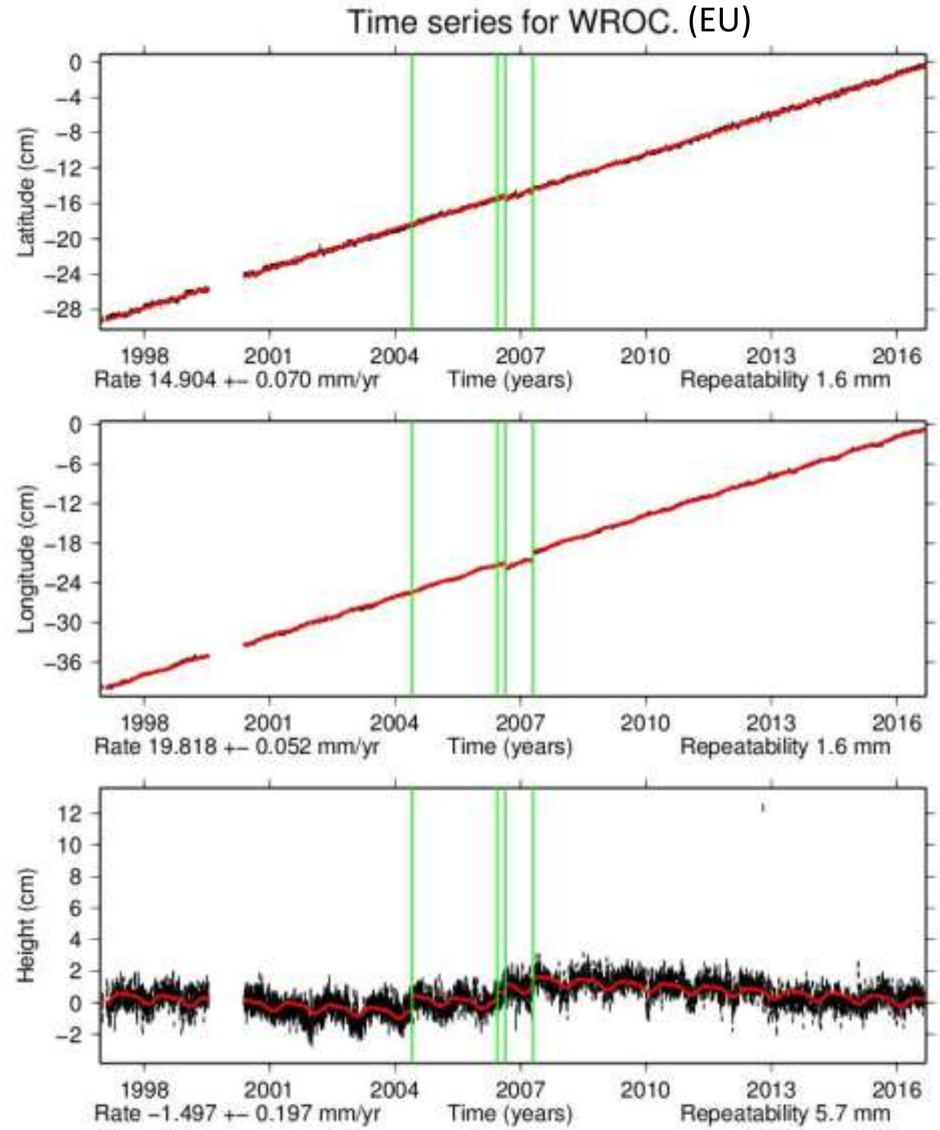

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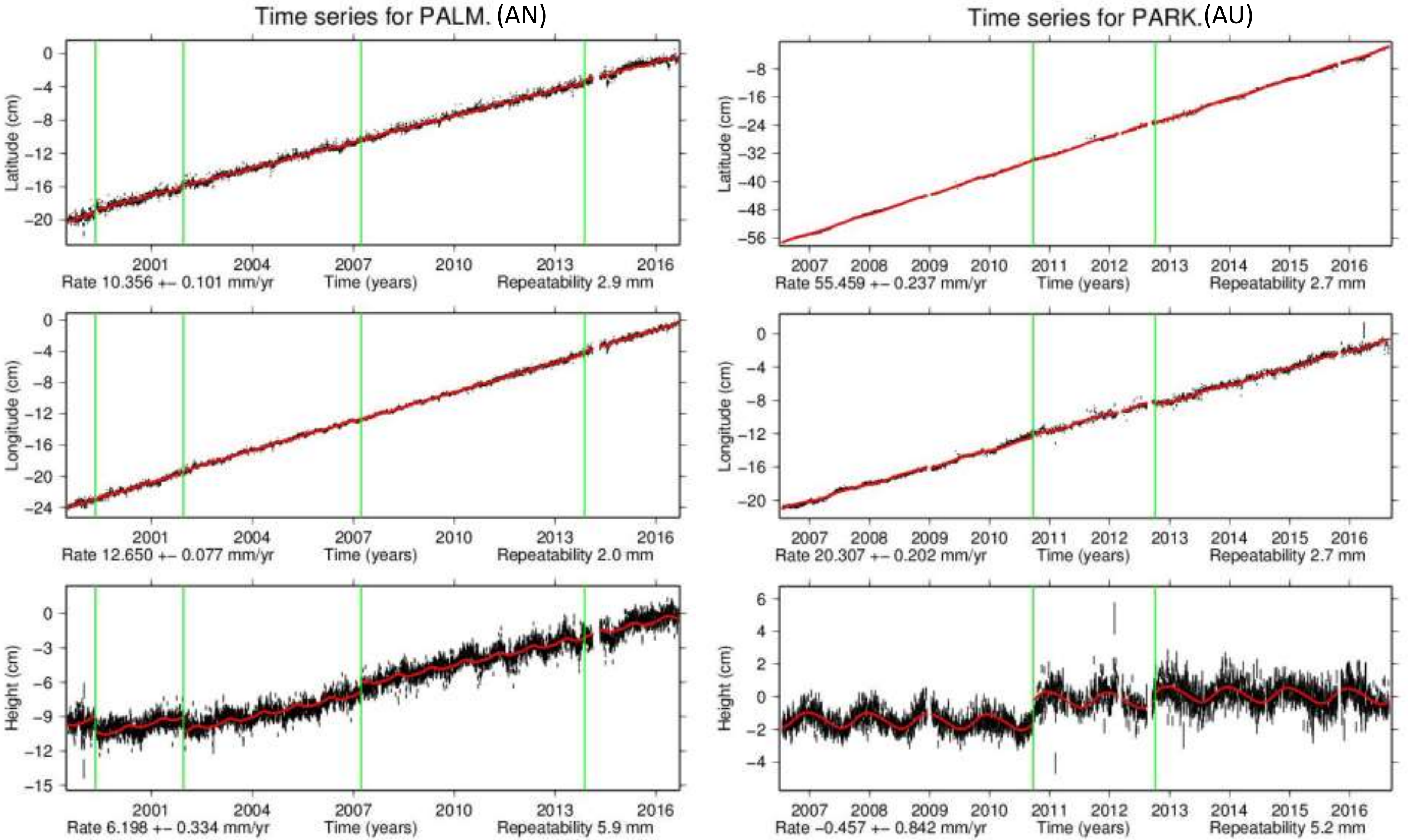


from sideshow.jpl.nasa.gov_post_series

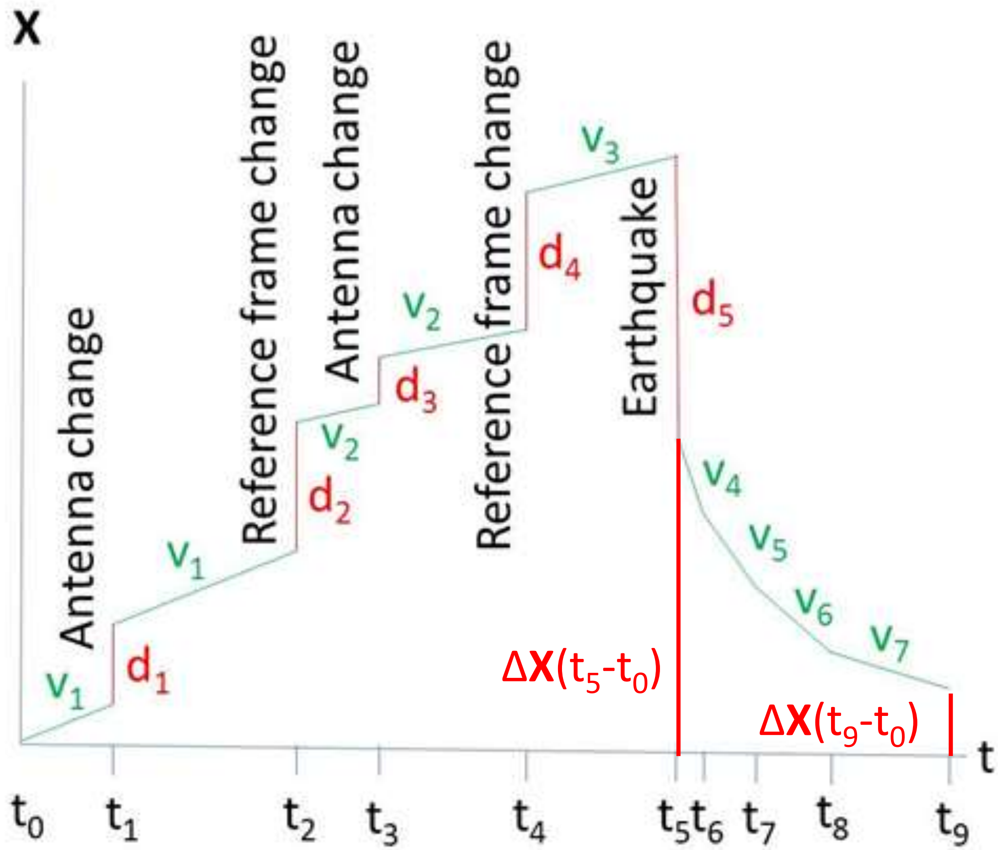
Presentation in the solution (SINEX) files: ITRF2014

DOMES NB.	SITE NAME	TECH.	ID.	X/Vx	Y/Vy	Z/Vz	Sigmas			SOLN	DATA_START	DATA_END
				m / m/y								
41719M001	Concepcion	SLR	7405	1492033.2042	-4887946.0857	-3803565.8113	0.0008	0.0005	0.0005	1	00:000:00000	10:058:23656
41719M001				0.03462	-.00102	0.01801	.00017	.00016	.00014			
41719M001	Concepcion	SLR	740 5	1492030.2242	-4887946.5381	-3803566.3274	0.0013	0.0011	0.0010	3	10:064:42427	11:043:04621
41719M001				0.03229	0.00517	0.02210	.00081	.00075	.00064			
41719M001	Concepcion	SLR	7405	1492030.2044	-4887946.5408	-3803566.3218	0.0023	0.0021	0.0017	4	11:043:04621	00:000:00000
41719M001				0.03229	0.00517	0.02210	.00081	.00075	.00064			
41719S001	Concepcion	VLBI	7640	1492054.4191	-4887961.0112	-3803541.2396	0.0013	0.0018	0.0016	1	00:000:00000	10:058:23656
41719S001				0.03566	-.00130	0.01721	.00009	.00017	.00015			
41719S001	Concepcion	VLBI	7640	1492051.4391	-4887961.4705	-3803541.7533	0.0010	0.0018	0.0016	3	10:064:42427	11:043:04621
41719S001				0.03108	0.00552	0.02275	.00036	.00076	.00061			
41719S001	Concepcion	VLBI	7640	1492051.4153	-4887961.4862	-3803541.7369	0.0012	0.0022	0.0019	4	11:043:04621	00:000:00000
41719S001				0.03108	0.00552	0.02275	.00036	.00076	.00061			
41719M002	Concepcion	GNSS	CONZ	1492007.7586	-4887910.7344	-3803639.8471	0.0006	0.0006	0.0007	3	05:137:52200	10:058:23656
41719M002				0.03582	-.00109	0.01782	.00004	.00004	.00005			
41719M002	Concepcion	GNSS	CONZ	1492004.8112	-4887911.1659	-3803640.3666	0.0010	0.0020	0.0015	4	10:058:23656	10:064:42427
41719M002				0.03200	0.00388	0.02301	.00004	.00006	.00005			
41719M002	Concepcion	GNSS	CONZ	1492004.7679	-4887911.1871	-3803640.3584	0.0006	0.0006	0.0007	5	10:064:42427	11:043:04621
41719M002				0.03200	0.00388	0.02301	.00004	.00006	.00005			
41719M002	Concepcion	GNSS	CONZ	1492004.7492	-4887911.1992	-3803640.3426	0.0006	0.0006	0.0007	7	11:200:73800	00:000:00000
41719M002				0.03200	0.00388	0.02301	.00004	.00006	.00005			
41719M004	Concepcion	GNSS	CONT	1492032.7729	-4887961.1825	-3803553.6226	0.0006	0.0006	0.0007	1	00:000:00000	10:058:23656
41719M004				0.03582	-.00109	0.01782	.00004	.00004	.00005			
41719M004	Concepcion	GNSS	CONT	1492029.7865	-4887961.6219	-3803554.1450	0.0006	0.0006	0.0007	3	10:064:42427	11:042:72331
41719M004				0.03199	0.00388	0.02301	.00004	.00006	.00005			
41719M004	Concepcion	GNSS	CONT	1492029.7629	-4887961.6316	-3803554.1290	0.0006	0.0006	0.0007	4	11:042:72331	00:000:00000
41719M004				0.03199	0.00388	0.02301	.00004	.00006	.00005			

Alternative approach to varying velocities

Instead of extrapolating the station coordinates stepwise over all the periods, one could use the differences of epoch solutions (e.g. weekly):

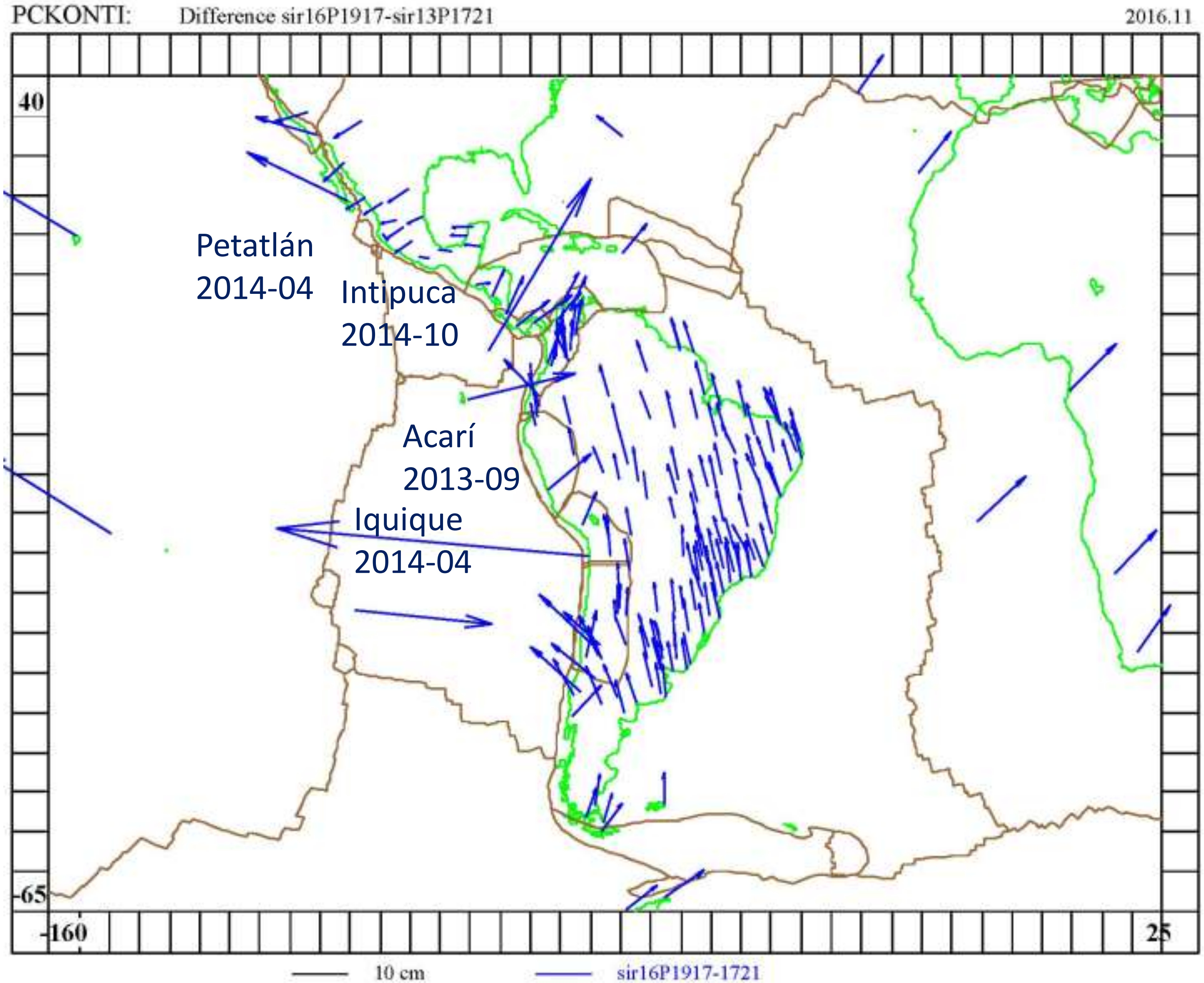
$$\Delta \mathbf{X} = \mathbf{X}(t_i) - \mathbf{X}(t_0)$$



The differences include all the effects: changes of velocities and reference frame, seismic discontinuities, and all type of other non-linear motions.

For new stations one has to interpolate discontinuities $\Delta \mathbf{X}$ between the geographical positions instead of velocities and their extrapolation.

Coordinate differences SIRGAS 2016.75 – 2013.01

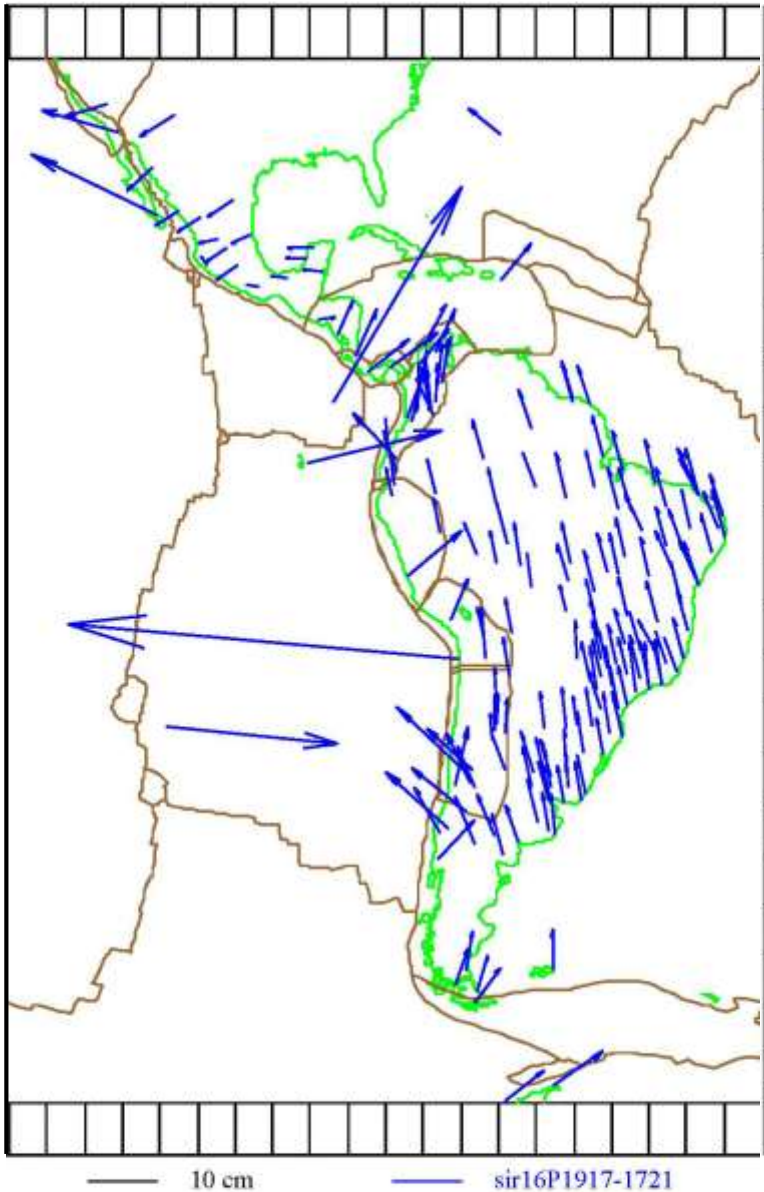


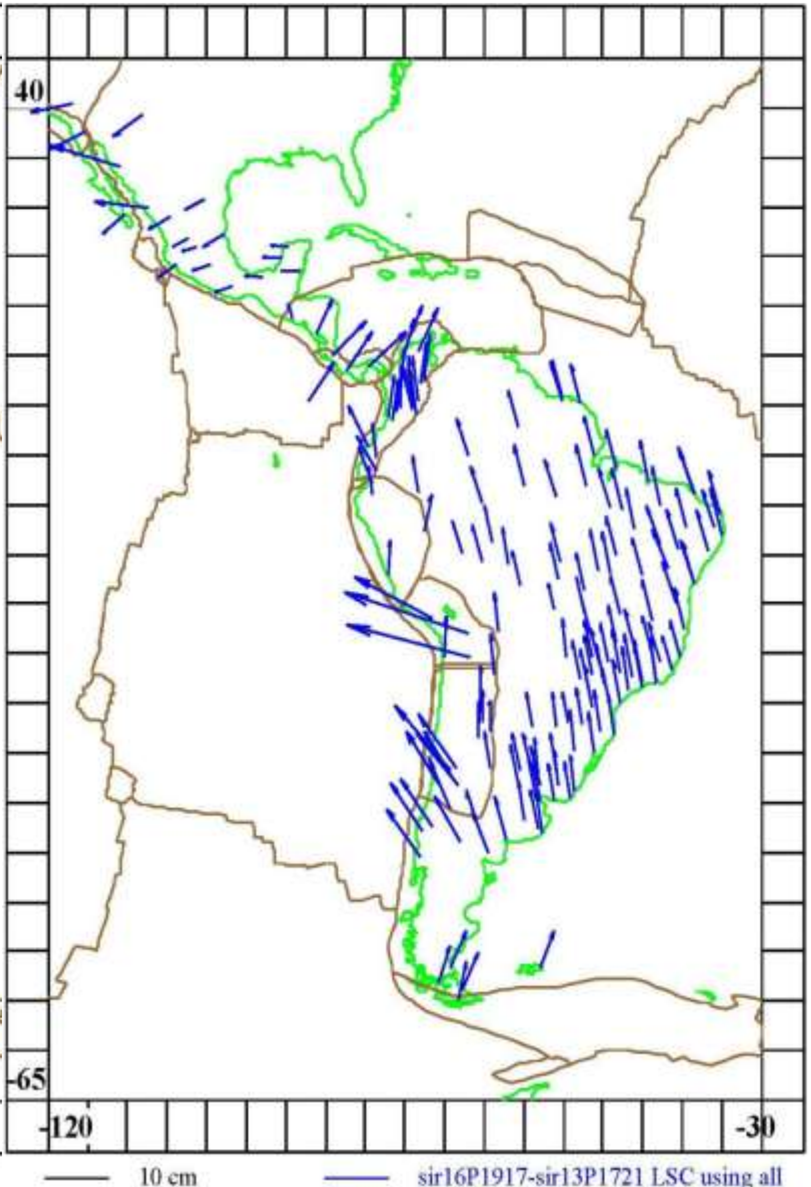
sir16P1917 – sir13P1721 (www.sirgas.org)

Differences reflect mainly the movement of the tectonic plates, but also displacements of earthquakes:

Acarí, PE 7.1,
Iquique, CL 8.2,
Petatlán, MX 7.2,
Intipuca, SV 7.3

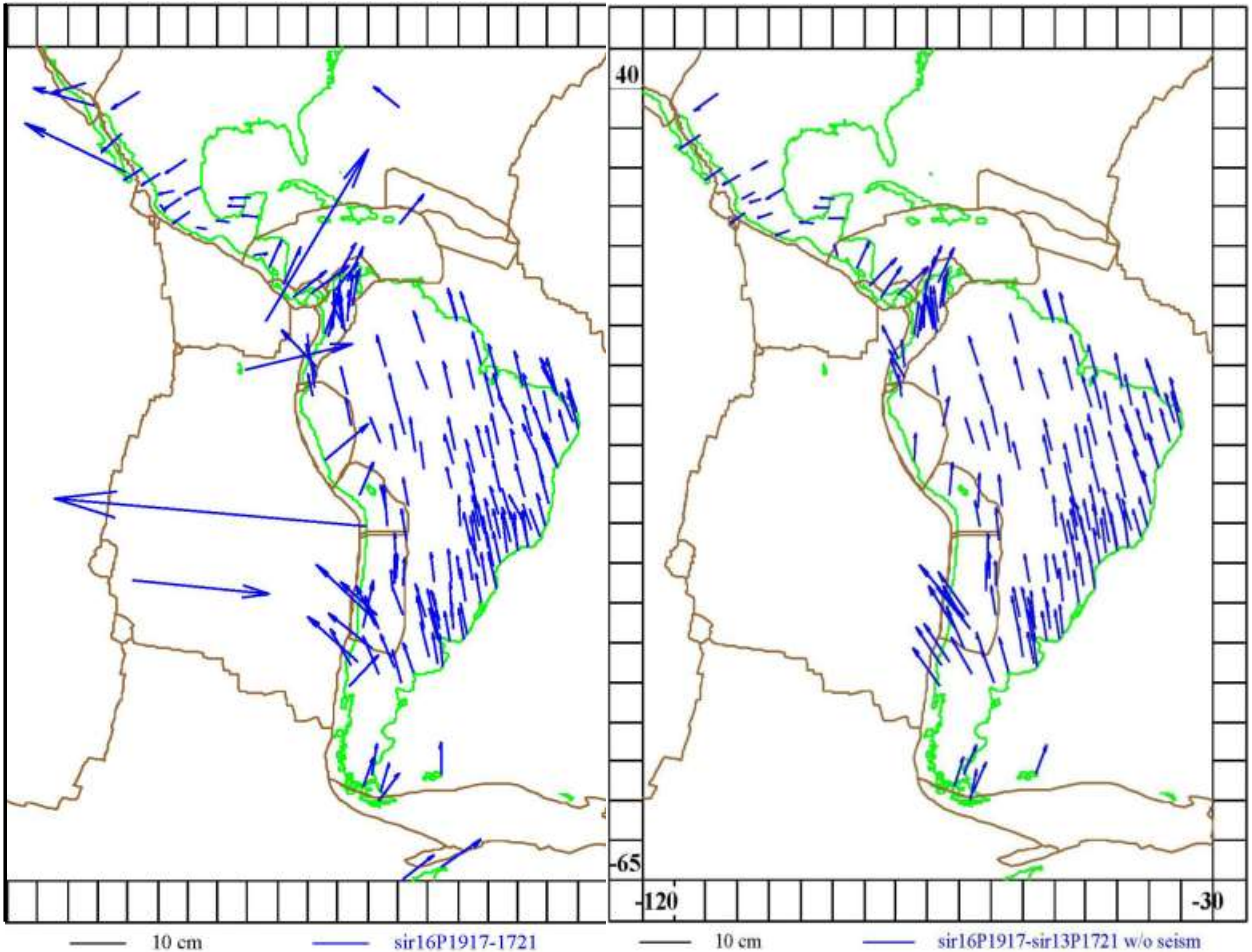
Observed and interpolated differences 2016.75 – 2013.01





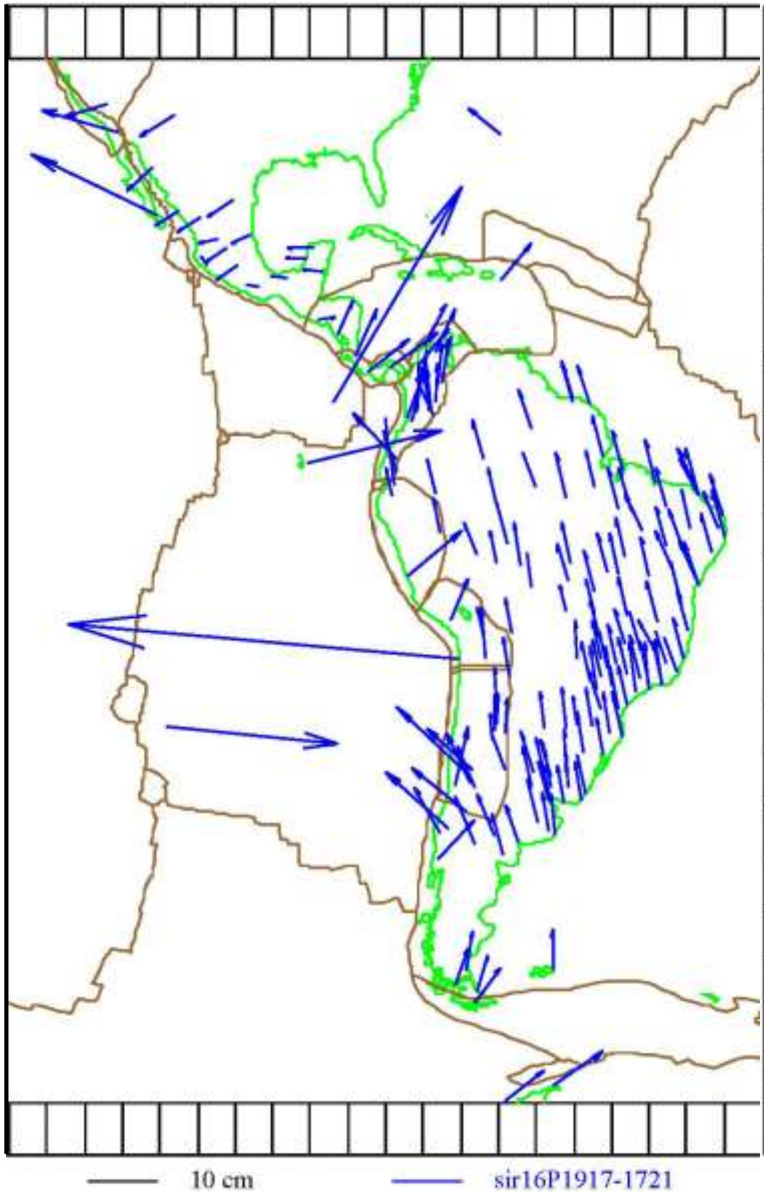
Comparison: sir16P1917 – sir13P1721 observed (left), and interpolated from all the observed differences without using the predicted point (right).

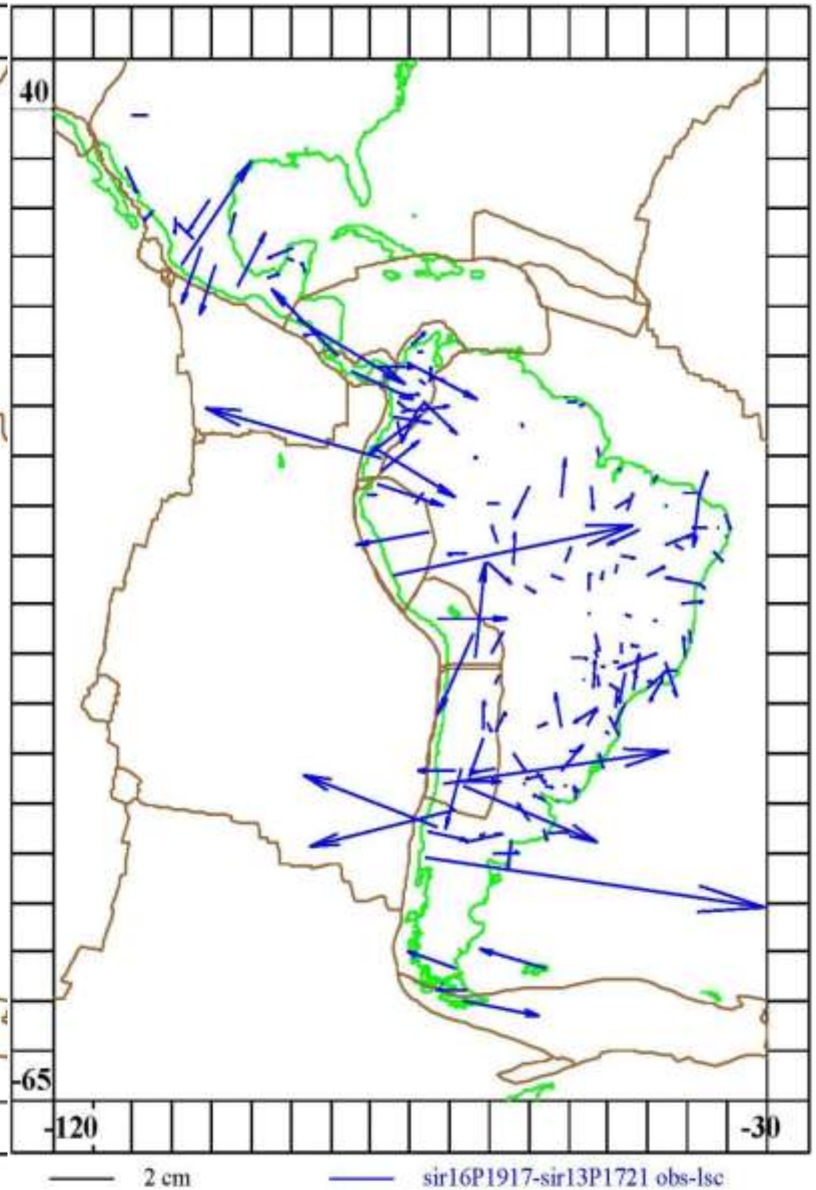
Observed and interpol. diff. 2016.75 – 2013.01 w/o seisms



Comparison: sir16P1917 – sir13P1721 observed (left), interpolated from observed differences except MEXI, IPAZ (PCFC), ISCO (COCO), GLPS (NAZC), and IQQE without using the predicted point (right).

Observed and interpol. diff. 2016.75 – 2013.01 w/o seisms



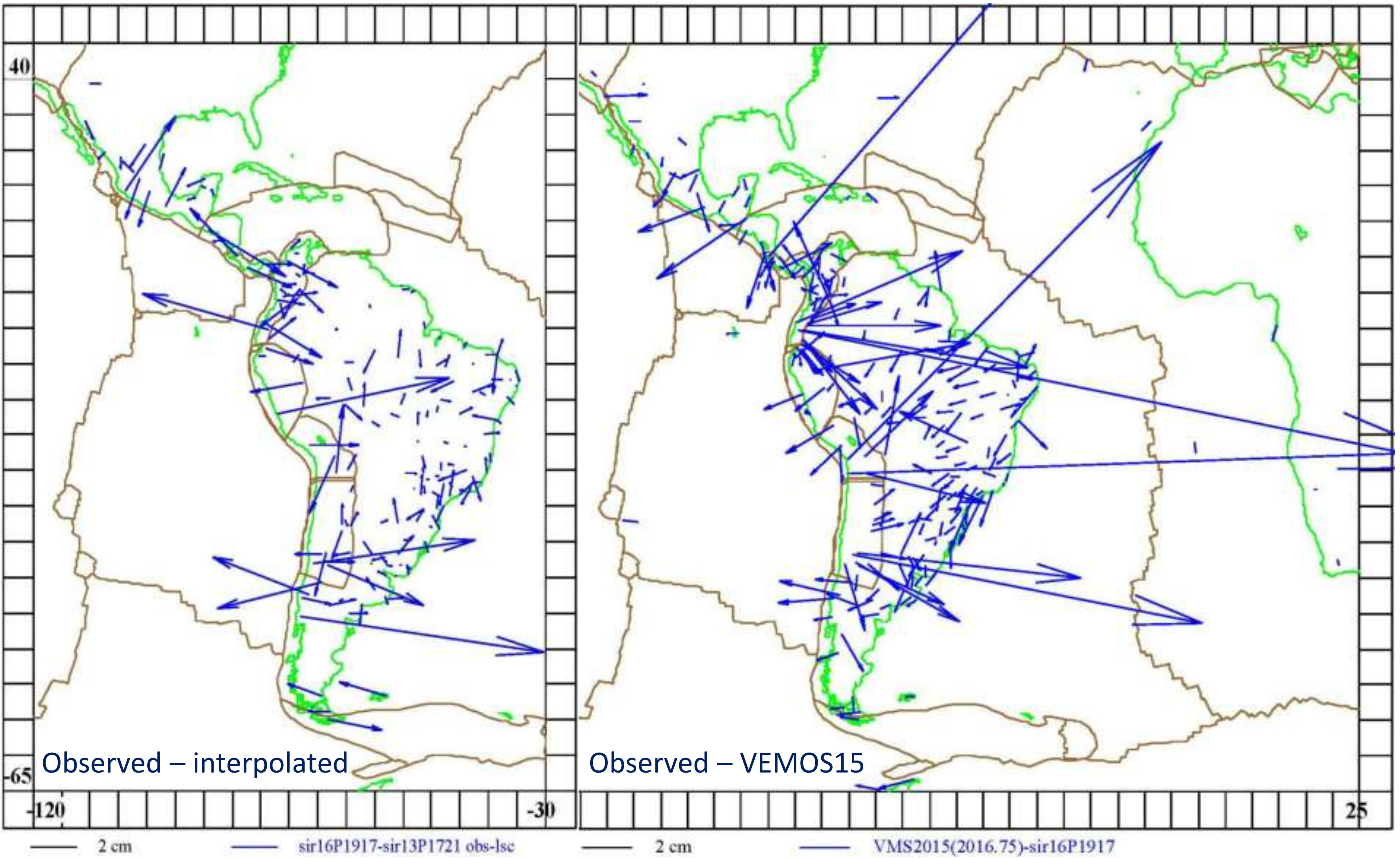


Differences sir16P1917 – sir13P1721 observed (left).

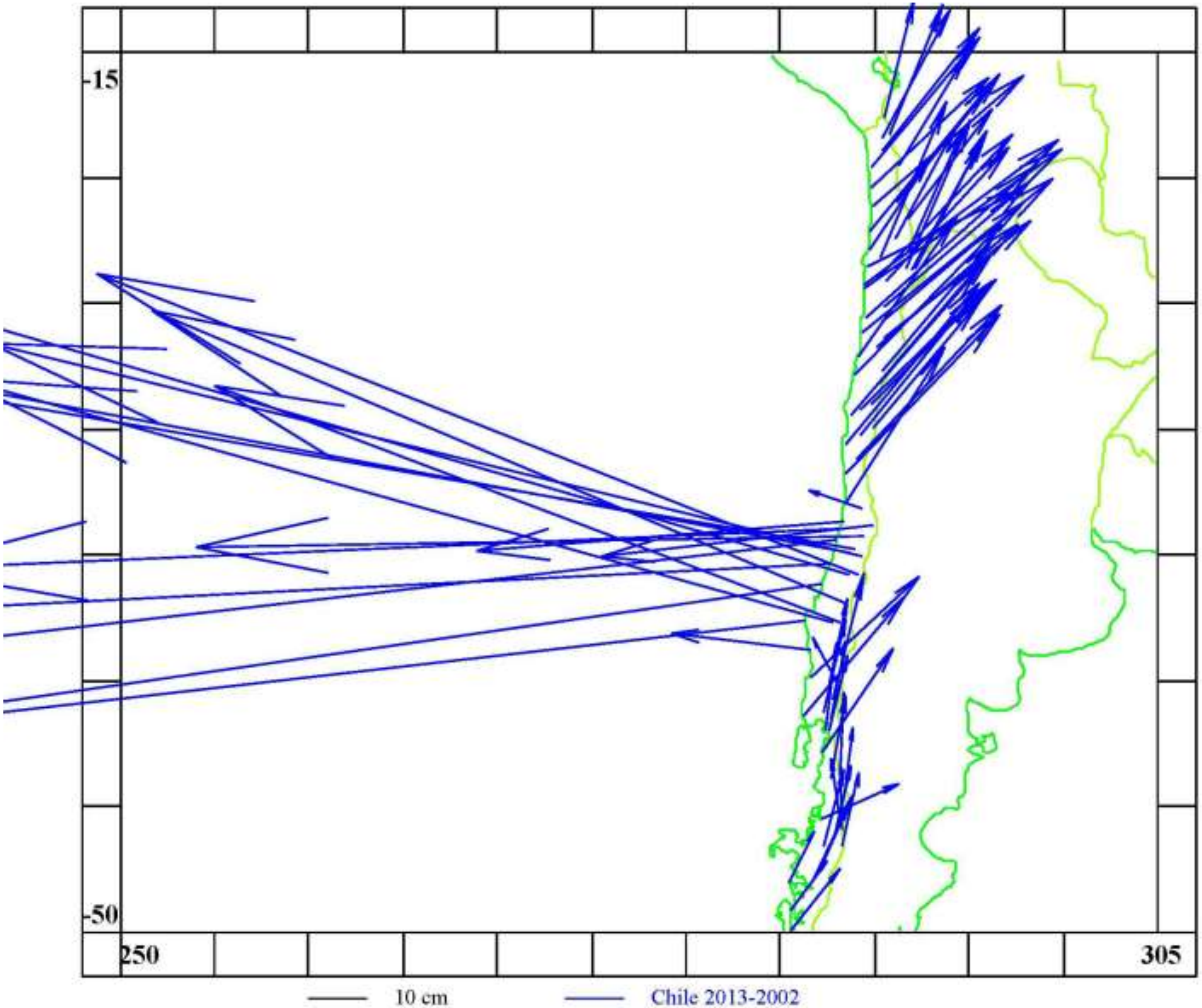
Differences between obs. (except MEXI, IPAZ (PCFC), ISCO (COCO), GLPS (NAZC), & IQQE), and interpolated (right).

Observe the different scale!

Differences 2016.75 – 2013.01 inter- and extrapolated



Long-term regional differences: Chile 2013 - 2002



From Hector Parra
25 November 2015

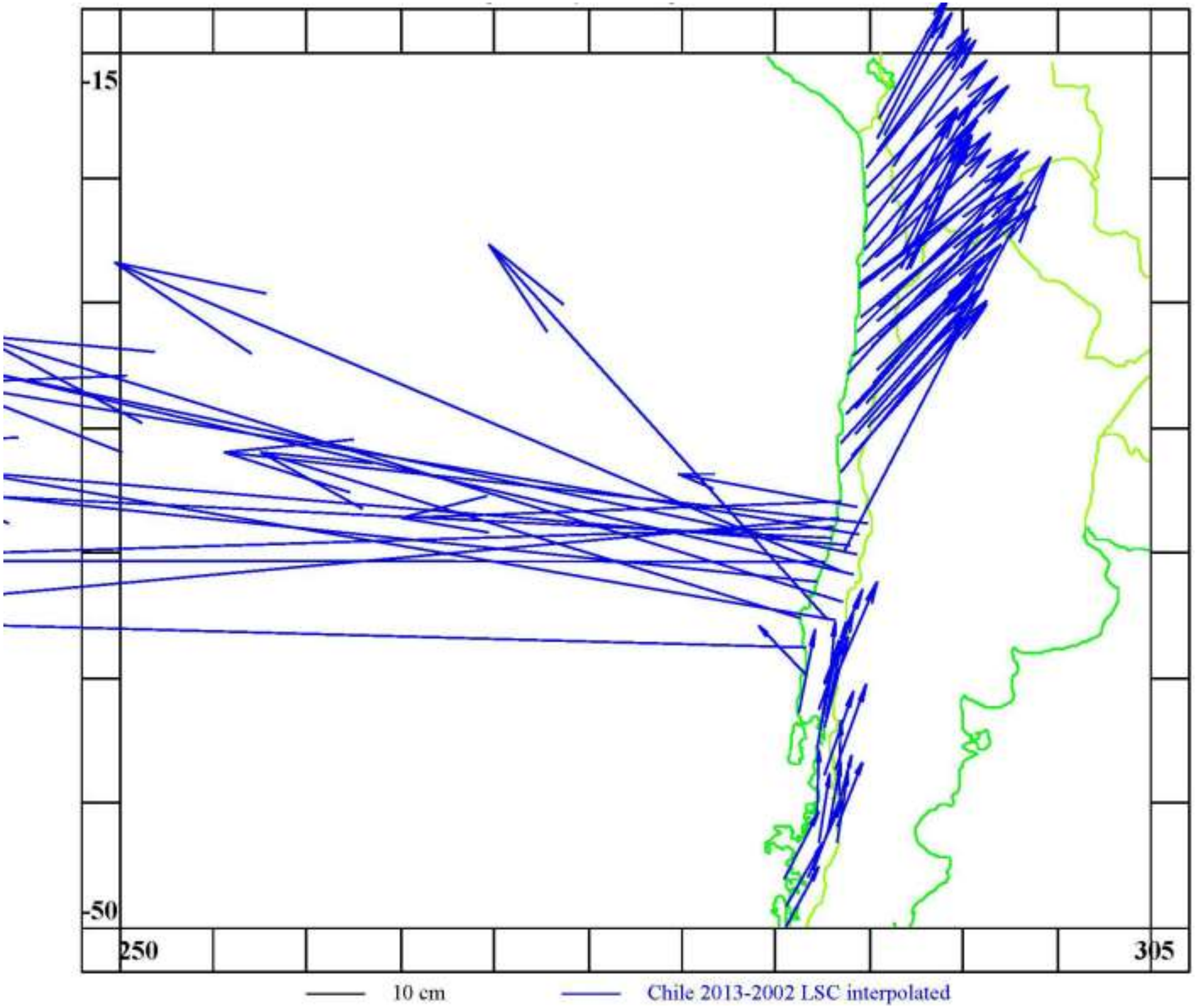
Maximum differences:

N: -0.48 … 0.49 m

E: -4.76 … 0.34 m

h: -0.35 … 1.31 m

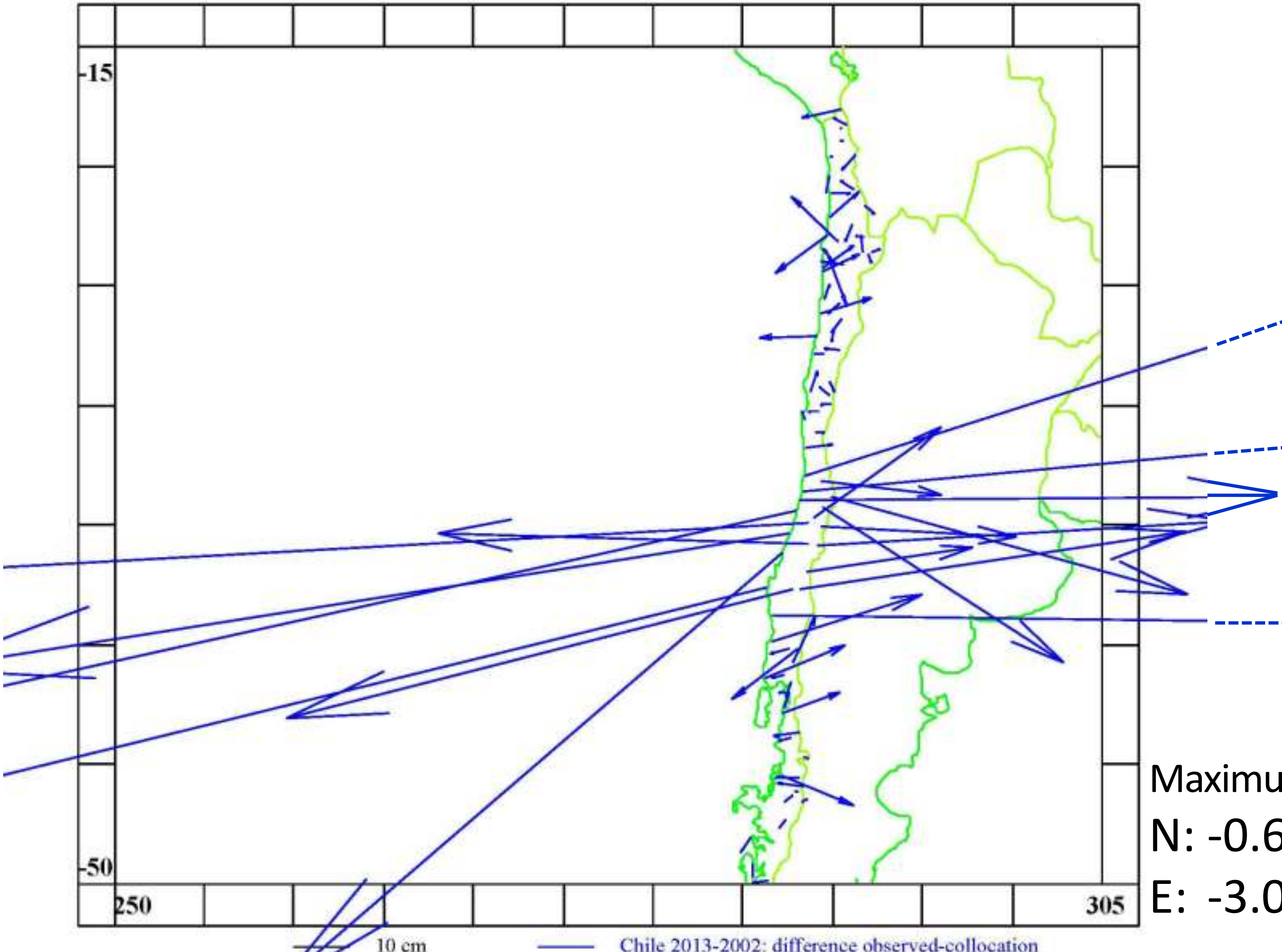
Chile 2013 – 2002 interpolated by LSC



Least squares collocation without using the point to be interpolated

RMS LSC error:
N: < ± 0.47 m
E: < ± 1.68 m

Chile 2013 – 2002 interpolated by LSC



Maximum differences:

N: -0.69 … 0.26 m

E: -3.06 … 2.23 m

Conclusiones

La extrapolación de coordenadas (**X**) con velocidades constantes (**dX/dt**) es un problema en zonas sísmicas.

Además de desplazamientos sísmicos hay que considerar movimientos no lineares (estacionales y a largo plazo), cambios de antenas y del sistema de referencia.

En períodos entre terremotos se recomienda no utilizar velocidades (que cambian durante mucho tiempo) sino diferencias de coordenadas epocales (p.ej. semanales) en las estaciones de referencia e interpolar las diferencias geográficamente para puntos nuevos.

La interpolación pasando eventos sísmicos graves o fallas tectónicas (placas) no es recomendable en caso de desplazamientos grandes.

En zonas sísmicas se necesitan muchas estaciones GNSS de medición contínua (distancia < 100 km) para detectar desplazamientos.

Después de sismos graves se recomienda establecer un marco de referencia nuevo para garantizar la continuidad de coordenadas.

Conclusions

Thank you very much for your attention!
¡Muchas gracias por su atención!